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XXXVIII. The 2004 Western Bedrock Valley Statistical Report
51 Eames Street Site, Wilmington, MA
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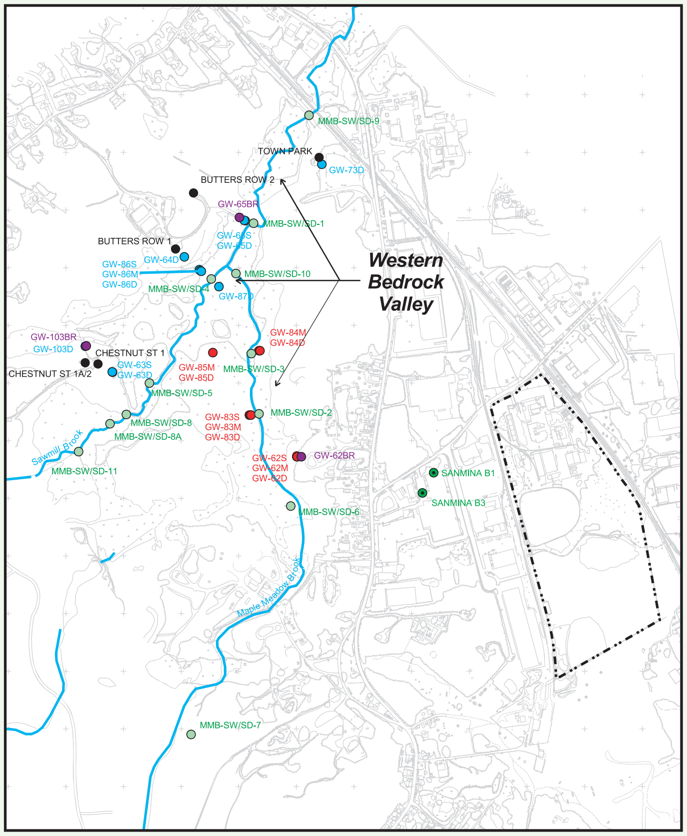

Prepared for:

Olin Corporation
Wilmington, MA Facility

August 4, 2005

GEOMEGA

GOOD SCIENCE • HARD WORK • CREATIVE THINKING

The 2004 Western Bedrock Valley Statistical Report
51 Eames Street Site, Wilmington, MA
RTN: 3-0471

August 4, 2005

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Executive Summary

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This report presents the most recent statistical evaluation of data collected as part of the Western Bedrock Valley Groundwater Monitoring Program, as described in the "Western Bedrock Valley Ground-water Monitoring Report, June 2003 – December 2004" (MACTEC 2005a). In addition, quarterly surface water quality data collected from the Maple Meadow Brook and Sawmill Brook beginning in October 2003 are analyzed and discussed.

The statistical evaluations described herein address the requirements of the Massachusetts Department of Environmental Protection (MADEP), as set forth in MADEP's letter to Olin Corporation (Olin) dated January 12, 1999. Specifically, this report presents findings based upon the most recent groundwater data collected from portions of the 51 Eames Street Site (the Site) in Wilmington, MA, which is proximate to the Town of Wilmington Water Supply Wells (WSWs), generally referred to as the Western Bedrock Valley (WBV). This report updates the previous WBV statistical report (Geomega 2004), which was submitted to MADEP in May 2004, and incorporates groundwater data collected between June 2003 and December 2004 (the monitoring period).

Historically, the purpose of the statistical evaluation was to (1) assess chemical trends in groundwater, (2) evaluate the possible relationships between pumping rates and solute concentrations in the active WSWs and nearby wells, and (3) determine if solute concentrations in groundwater in the WBV exhibit predictable trends. As of February 2003, all of the WSWs located within the Maple Meadow Brook Aquifer (MMBA), proximate to the WBV, were taken out of service due to the detection of N-nitrosodimethylamine (NDMA) in four of the five WSWs.

MADEP approved the suspension of monthly and quarterly monitoring of the WSWs in May 2003. In October 2003, Olin initiated a surface water sampling plan, which included the quarterly sampling and analysis of surface water from 11 locations within the Maple Meadow and Sawmill Brooks. This sampling plan was described in a letter from GEI to MADEP, dated August 25, 2003. Subsequently, MADEP requested that Olin provide supplemental information to support the proposed sampling plan, which was submitted to MADEP on April 5, 2004 and February 22, 2005, respectively.

The statistical evaluation presented in this report considers key solutes and groundwater and surface water quality characteristics that are generally indicative of water quality impacts associated with the Site between June 2003 and December 2004, relative to earlier time periods. The key indicator parameters include chloride, ammonia (as nitrogen), sodium, sulfate, and specific conductance. Other contaminants of concern (COCs) that may be associated with the Site, including NDMA, are not addressed.

General Findings

Indicator parameter concentrations in the “Sentinel” monitoring wells near the Wilmington WSWs appear to be stabilizing since the cessation of pumping. Indicator parameter concentrations in the “Fate and Transport” wells in the WBV continue to be generally stable, with the exception of fluctuations in concentrations within the current monitoring period (both increasing and decreasing) in the deep wells.

The bedrock monitoring well concentrations and water quality indicators remained relatively stable during this monitoring period, with the exception of GW-103BR (located near the Chestnut Street wells), which has shown a decrease in concentrations since the cessation of pumping. Concentrations in the Sanmina wells continued to vary with pumping rate, but did not suggest that any substantial change in aquifer conditions or plume behavior had taken place.

Indicator solute concentrations in selected wells may be stabilizing relative to new baselines that reflect predicted changes in aquifer conditions following the cessation of WSW pumping. As such, this groundwater monitoring period reflects a transition to post-pumping conditions. During this transition or stabilization period, results from the statistical analyses should be treated cautiously, because apparent changes in solute concentrations could be misinterpreted to indicate significant mobilization of Site-related constituents. Modifications to future statistical comparisons are currently being considered to appropriately address these expected and ongoing changes in aquifer condition.

The surface water quality sampling results from the Maple Meadow and Sawmill Brooks are dominated by temporal (seasonal) and spatial variability in certain indicator parameter concentrations. This variability is consistent with the dynamic hydrologic conditions and natural chemical processes in wetlands environments. In addition, surface water quality impacts from deicing road-salt runoff are evident. Although the new data collected during this sampling period contribute significantly to the amount of surface water quality data that has been collected historically (prior to the fourth quarter 2003), the limited data set precludes application of robust quantitative statistical methods to the data. As a result, additional quarterly monitoring data will be required to develop reliable statistical analyses for surface water quality.

Considerations for the MMBA Monitoring Plan

The information and results presented in this evaluation report support the continuation of the MMBA monitoring plan without modification (although limited changes supporting the statistical methods may be warranted). Specifically:

- Concentrations of indicator parameters in the Sentinel wells near the WSWs appear to be stabilizing, while concentrations in wells in the WBV are exhibiting minor fluctuations. Although the monitoring well network continues to serve as a functional indicator of groundwater quality and of the dynamic behavior of the COC plume, modifications to the background data window used to calculate statistical limits may be warranted in order to continue to provide a reliable monitoring program.

- Concentrations in well GW-103BR (near the Chestnut Street wells) have dropped and appear to be stabilizing in response to the cessation of pumping. Data and trends from wells GW-62BR and GW-65BR are consistent with previous analyses.

- Concentrations in the Sanmina supply wells continued to vary with pumping rates, but did not reflect significant changes or large-scale mobilization of the local COC plume.

- Data collected from the Sentinel well monitoring program will continue to be incorporated into the statistical tests used to assess the stability of or temporal changes in groundwater solute concentrations. Screening of quarterly data based upon these statistical analyses will result in decisions requiring no further action, data verification, or some other action. If required, verification resampling will be performed within one month after a statistical exceedance has been identified. If an exceedance is verified through resampling, MADEP will be consulted and a consensual response developed.

- This groundwater monitoring period reflects a transition from pre- to post-pumping conditions. The changes in aquifer conditions related to the cessation of pumping from the WSWs may necessitate a re-examination of the data sets used to calculate background condition statistical limits. Groundwater quality data collected following the cessation of pumping may be used to form the basis of new statistical limits. These new calculated limits could provide a more representative baseline for future statistical comparisons.

- The quarterly sampling data from the surface water monitoring network show pronounced temporal (seasonal) variability in select monitoring parameters. This variability is associated with those parameters most sensitive to redox conditions. If the observed magnitude of this seasonal variability continues, additional quarterly monitoring data will be required in order to provide sufficient data to incorporate this variability into robust statistical analyses. In addition, water quality impacts from deicing road-salt runoff (NaCl) are indicated within the Sawmill Brook and the Maple Meadow Brook.

- Based on the observed fluctuations in groundwater quality, the temporal and spatial variability of surface water quality, and the potential need to further relate surface and groundwater chemistry, continued sample collection under the requirements of the current MMBA monitoring program will provide the data and information necessary for future statistical analyses. Modifications and enhancements to future statistical comparisons are currently being considered to appropriately accommodate expected and ongoing changes in aquifer condition while providing the ability to detect anomalous or adverse changes in groundwater and surface water quality.

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1 Introduction

This report presents the findings of the most recent statistical evaluation of groundwater samples collected from portions of the 51 Eames Street Site in Wilmington, MA, that are proximate to the Town of Wilmington Water Supply Wells (WSWs), generally referred to herein as the Western Bedrock Valley (WBV)[1] (Figure 1). This report updates the previous statistical report (Geomega 2004), which was submitted to the Massachusetts Department of Environmental Protection (MADEP) in May 2004, and incorporates groundwater data collected in the WBV between June 2003 and December 2004 (the monitoring period), as summarized in the "Western Bedrock Valley Ground-water Monitoring Report, June 2003 – December 2004," prepared by MACTEC Engineering and Consulting, Inc., and dated June 2005 (MACTEC 2005a). This report also presents an analysis of data from the Sanmina supply wells, which were collected by Olin Corporation (Olin) during the same period and are also reported in the MACTEC report, and an analysis of quarterly surface water data collected by Olin during the period November 2003 to November 2004 in Maple Meadow Brook and Sawmill Brook (MACTEC 2005b).

Historically, the purpose of the statistical evaluation was to (1) assess chemical trends, (2) evaluate the possible relationships between pumping rates and solute concentrations in the active WSWs and nearby wells, and (3) determine if solute concentrations in groundwater in the WBV exhibit predictable trends. As of February 2003, all of the WSWs located within the Maple Meadow Brook Aquifer (MMBA), proximate to the WBV, were taken out of service due to the detection of N-nitrosodimethylamine (NDMA) in four of the five WSWs.

MADEP approved the suspension of monthly and quarterly monitoring of the WSWs in May 2003. In October 2003, Olin initiated a surface water sampling plan, which included the quarterly sampling and analysis of surface water from 11 locations within the Maple Meadow and Sawmill Brooks. This sampling plan was described in a letter from GEI to MADEP, dated August 25, 2003. Subsequently, MADEP requested that Olin provide

[1] The WBV is a geologic feature located within the Maple Meadow Brook Aquifer Study Area, a portion of the Olin Site located generally west of Main Street, in Wilmington. MA.

supplemental information to support the proposed sampling plan, which was submitted to MADEP under separate cover on April 5, 2004.

The statistical evaluation presented in this report considers key solutes and groundwater/surface water quality characteristics that are generally indicative of water quality impacts associated with the Site between June 2003 and December 2004, relative to earlier time periods. The key parameters include chloride, ammonia (as nitrogen), sodium, sulfate, and specific conductance. Other contaminants of concern (COCs) that may be associated with the Site, including NDMA, are not addressed.

Quarterly surface water quality data collected from the Maple Meadow and Sawmill Brooks beginning in October 2003 are discussed herein. However, the current data set for surface water collected under non-pumping conditions are not sufficient to select or apply a rigorous statistical analytical method at this time. Concurrent with ongoing data collection efforts, Geomega is evaluating statistical methods that will appropriately incorporate seasonal trends while providing sufficient sensitivity to detect anomalous changes in water quality.

1.1 Statistical Treatment of Data

The chemical data collected at the WBV monitoring wells were analyzed to evaluate statistically significant trends in solute concentrations. Periodic evaluation of the WBV monitoring wells (Figure 1) is intended to provide an early warning system for changes in solute concentrations in the MMBA, and aids in understanding the fate and transport of COCs in the aquifer. Water quality data from eleven surface water sampling locations in the Maple Meadow and Sawmill brooks are also considered (Figure 1). In addition, data obtained from three wells completed in bedrock (GW-62BR, GW-65BR, and GW-103BR) and the two Sanmina supply wells (B1 and B3) were also analyzed for trends. The analyses were based on data collected through December 2004, as reported in MACTEC (2005a).

The goals of this analysis were to:

- assess groundwater chemical concentration trends, if any, in the MMBA,
- determine if solutes in monitoring wells exhibit predictable trends,

- determine if the surface water monitoring program is providing data suitable for identifying changing water quality conditions in the wetlands, and

- provide a basis for reevaluating the existing MMBA monitoring program in light of recent hydraulic changes in the aquifer (e.g., the cessation of pumping at the Wilmington WSWs).

The current analyses followed the recommendations made in the original scope-of-work (Geomega 1998). Concentrations of five key parameters (ammonia, chloride, sodium, specific conductance, and sulfate) were analyzed from the Sentinel wells and the WBV wells, the three bedrock wells, the Sanmina supply wells, and surface water locations.

The sampling frequency varies by well group (MACTEC 2005a, Table 2-1). The WSWs were not sampled during this period. Some of the WBV wells (the "Sentinel Wells" GW-63S&D, GW-64D, GW-65S&D, GW-73D, GW-86S&M&D, GW-87D, and GW-103D) are sampled quarterly, while others (the "Fate and Transport Wells" in the WBV, GW-62S&M&D, GW-83S&M&D, GW-84M&D, and GW-85M&D) are sampled semi-annually. The bedrock wells are sampled annually with the exception of GW-103BR, which is sampled quarterly, the Sanmina supply wells are sampled monthly, and the surface water locations are sampled quarterly.

The objective of the statistical evaluation is to determine whether solute concentrations in the WBV monitoring wells and other wells, and in the Maple Meadow Brook and Sawmill Brook, are increasing, decreasing, or have reached a stable condition. This analysis requires that the parameter concentrations from each well be compared to historical concentrations by performing "intrawell" tests, wherein the historical data from each location are used as the baseline data to determine statistical limits. The intrawell tests examine changes at each location over time, and are unaffected by spatial heterogeneity in solute concentrations across the Site. Data obtained prior to the third quarter of 2003 were used as background data.

2 Statistical Approach

2.1 Methods

A sequence of routine steps was followed to determine if statistically significant changes have occurred in the concentrations of the five indicator parameters:

1. The number of samples and the percentage of samples with detected concentrations are determined for each sample location and parameter. If fewer than four sample values are available, no statistical tests are performed. If more than 50% of the data are reported as less than the laboratory detection limit ("non-detect"), the Shapiro-Wilk test and control chart analyses (described below) are not performed. The nonparametric Kendall test for trend can be performed on data with high percentages of non-detects, with the non-detects treated as tied values below the lowest detected concentration. The only dataset excluded for analyses in this reporting period is ammonia from well GW-103D with a rate of 67% non-detects (Table 1).

2. The Shapiro-Wilk normality test was performed on the background period data from the WSW and WBV wells to determine if a normal or log normal distribution best fit the data. Any constituent populations that were best described by a log normal distribution were transformed to a log scale before proceeding to the next step.

3. For the WSW and WBV wells, recent data were compared to historical background concentrations from that well (intrawell test) using the combined Shewhart/CUSUM control chart. Data prior to the third-quarter 2003 were used as the historical background. If the background period data exhibited a significant trend, the trend was removed prior to calculating the background statistics. This method was used both as an initial screen for outliers and as an indicator of trend.

4. The Kendall test for trend (Gibbons 1994; Gilbert 1987) was applied to test for significant changes over time in all wells. The results of the trend tests were compared to the results of the Shewhart/CUSUM control charts for the WSWs and the WBV wells.

These methods are recommended to quantitatively analyze the results of long-term groundwater monitoring programs and to determine if evolving groundwater quality meets or exceeds numerical standards or risk-based criteria (Gibbons 1994; Starks 1989; USEPA 1989, 1992). The control chart calculations and graphics for these analyses were produced using functions provided in the S-Plus statistical software package. Functions for the Kendall test for trend and Cohen's Maximum Likelihood Estimator to calculate means and standard deviations for data with non-detects were provided in Environmental Stats for S-Plus (Millard 2002).

2.2 Step 1: Testing for Normality

The Shapiro-Wilk test for normality (the *W*-statistic) was computed to determine if the non-transformed or the natural-log converted data best met the assumption of normality required for parametric statistical tests. The test was applied to the background period (prior to third-quarter 2003) data. The Kendall test for trend (see below) was applied to the background data prior to the analysis. If a significant trend was observed, the trend was removed from the data and the test performed on the residuals.

The *W*-statistic is similar to a correlation coefficient, measuring the fit of the data to the expected values from the standard normal distribution. A higher value of *W* indicates that the data are more normally distributed. The *p*-value is the probability of obtaining a value for *W* that is as high as or higher than that observed. Therefore, higher *p*-values also indicate that the data is more normally distributed. This analysis demonstrates that some constituents (Table 1, bold and italicized values) are log normally distributed, but the majority follow a standard Gaussian (normal) distribution.

2.3 Step 2: Assessing Deviations

The use of Shewhart and CUSUM quality control charts for intrawell statistical comparisons has been recommended by both the U.S. Environmental Protection Agency (USEPA 1992) and others (Starks 1989; Gibbons 1994). This suite of tests is applicable when there is a background period of record with no impacts at the well. Although impacts to the WSWs have been documented since as early as 1967 for chloride (Whitman and Howard 1974), by removing the trend from the background period data prior to calculating the background statistics, the tests remain very sensitive to any continuing trends.

When used in conjunction with each other, the Shewhart and CUSUM charts represent a statistically robust decision tool to determine if solute concentrations in the wells are increasing or decreasing, either on a short-term or long-term basis. Both charts must be used together because there are instances when the CUSUM chart will not provide an accurate depiction of data trends, while on other occasions the Shewhart chart will not provide the sensitivity required to depict a true shift in the mean.

2.3.1 Shewhart Chart Method

The Shewhart Control Chart compares the analytical results relative to the background mean and is very sensitive to sudden changes in parameter concentration. An Upper Control Limit (UPCL) and a Lower Control Limit (LCL) were calculated from:

$$UPCL = x + Zs \qquad \textbf{(1)}$$

and

$$LCL = x - Zs \qquad \textbf{(2)}$$

where x is the background mean, s is the background standard deviation, and Z is used to establish the upper and lower percentage points of the normal distribution. If a trend was observed in the background data, the trend was removed and the standard deviation calculated using the residuals, which removes the bias in the standard deviation produced by the trend (Gibbons 1994).

For groundwater monitoring programs with small background populations, setting $Z = 4.5$ results in a 95% confidence limit, as established by statistical power analyses based on Monte Carlo simulations for multiple comparisons (Starks 1989; USEPA 1992; Gibbons 1994). After the control limits are established, results for each sampling event are plotted sequentially so that variations in results relative to the background mean are clearly apparent, as are exceedances of the control limits.

2.3.2 CUSUM Chart Method

The CUSUM chart tracks gradual changes in parameter concentration relative to background conditions. Background-normalized data are used to calculate changes in concentration relative to the background mean. The differences are summed at each event and plotted relative to the mean, the Upper Decision Boundary (UDB) and the Lower Decision Boundary (LDB). The UDB and LDB are set at $\pm 4.5s$, respectively. The Upper and Lower Cumulative Sums are calculated from:

$$U_i = \max[0, (z_i - k)+U_{i-1}] \quad \textbf{(3)}$$

and

$$L_i = \max[0, (-z_i - k)+L_{i-1}], \quad \textbf{(4)}$$

respectively, where $z_i = (r_i - x)/s$, r_i is the current sample value, and k is selected to be one-half the size of the desired detectable difference. A value of $k = 1$ is recommended for groundwater monitoring applications (USEPA 1989). The CUSUM chart accumulates changes in concentration relative to the background mean in standard deviation units. For example, if a concentration is 1.5 standard deviations above the background mean, the CUSUM value for that result will show an increase of 1.5 from the previous value. As with the Shewhart chart, if a trend existed in the background data, it was removed before calculating the standard deviation.

For each constituent, the plot is split, showing both the Upper Sum and the Lower Sum. In most detection monitoring programs, only the Upper Sum is displayed. However, for this analysis both Upper and Lower sums are shown to check for either an increase or a decrease in solute concentration.

2.3.3 Control Chart Decision Criteria

The control charts serve to screen for outliers to assess the need for verification resampling and to detect trends in concentration. In normal use, an exceedance has occurred if the data displayed in either the Shewhart or CUSUM charts are above the allowable limits (the UPCL or UDB, respectively). If either the previous or subsequent data point does not exceed the limit, it is possible that the result is a false positive.

While a data trend can occur that does not trigger a Shewhart chart exceedance, the CUSUM chart, by accumulating small changes in concentrations relative to the background mean, is very sensitive to gradual changes that may not be apparent in a simple time series plot. Hence, in combination these two charts provide substantial statistical power to detect solute concentration changes at a well.

The current Shewhart-CUSUM decision criteria are calculated based upon historical data collected under WSW pumping conditions. Following additional data collection and evaluation, these criteria may need to be updated in the future to reflect non-pumping conditions. The pumping-condition criteria have been retained in this analysis for comparison purposes only. The introduction or development of new statistical decision criteria is not appropriate at this time.[2]

2.4 Step 3: Evaluating Temporal Trends

The Kendall test is a nonparametric test based on ranking of a set of variables. Nonparametric tests do not depend upon the assumption of normality to be valid but do require that the data are independent. One advantage of this method (Gilbert 1987) is that the test is not adversely affected by missing data (i.e., irregular sampling intervals).

The test is based on the sum of the signs of the differences among all of the values in the data being tested. For this analysis the test was performed using EnvironmentalStats for S-Plus (Millard 1998), which computes the Z-statistic and p-value. A high positive or negative value for Z indicates a positive or negative trend (a Z value of ± 1.64 indicates significance). The p-value also indicates if the slope is significant, with $p<0.05$ indicating a significant slope.

[2] Gibbons (1999) and American Society for Testing and Materials (ASTM) standards recommend eight or more data points for reasonably precise estimates of the background (or baseline) mean and standard deviation.

3 Results of Statistical Tests

3.1 Shewhart/CUSUM Control Charts

The combined Shewhart/CUSUM control charts for the five key constituents in all wells are provided in Appendix A by well category. The background means, standard deviations, and statistical test results are summarized in Table 2. Of the 105 tests performed (five parameters in 21 wells), 13 resulted in CUSUM-only exceedances and 13 produced both Shewhart and CUSUM exceedances.

3.2 Kendall Tests for Trend

Of the 105 Kendall trend tests applied to quarterly averaged data for all parameters and wells for the entire period of record, 46 (44%) had significant increasing trends and 13 tests (12%) had significant decreasing trends (Table 3). Well GW-63D had increasing trends for all five parameters (Table 3), but showed no control chart exceedances (Table 2).

Of the 53 data sets with either a Shewhart/CUSUM exceedance or a positive Kendall test, 10 had positive results for all tests, nine had a positive Kendall test and CUSUM-only exceedances, 27 had positive Kendall trend tests but no control chart exceedances, three had CUSUM/Shewhart exceedances and no Kendall trend, and four had CUSUM-only exceedances with no Kendall trend (Table 4).

The Kendall trend test was applied to data from the bedrock monitoring wells (GW-62BR, GW-65BR, and GW-103BR) and the Sanmina supply wells (B1 and B3) for the same indicator parameters as for the other wells in this report; the results are presented in Tables 5 and 6, respectively.

4 Discussion

4.1 Town of Wilmington Supply Wells

In a previous statistical evaluation report (Geomega 2000), a detailed analysis of the relationship between the pumping rates and COC concentrations in the Chestnut Street and Butters Row wells was performed. For the Chestnut Street wells it was discovered that when the combined pumping rates of the two wells exceeded 600 GPM for three months, parameter concentrations would increase in CS-1. However, the relatively constant concentrations observed in CS-2 during those periods of elevated pumping suggested that CS-1 was intercepting most of the flow from areas with elevated concentrations of COCs. The Butters Row wells had a different response, with concentrations in BR-1 increasing over a narrow range of combined pumping rates. However, BR-2 did not show increases in concentration, again suggesting that BR-1 was intercepting flow from localized areas of concentrated COCs. These observations gave rise to the concept of “front” versus “back” wells.

In 2000, the Town of Wilmington substantially reduced pumping from the “front wells” (BR-1 and CS- 1). Consequently, the “back wells” (BR-2 and CS-2) provided most of the supply from early 2000 through 2002 (Figures 2 and 3). By early 2003, groundwater withdrawal at all of the WSWs ceased. The resulting changes in pumping regime affected solute concentrations in the WSWs and nearby WBV wells, as evidenced by the occurrence of new significant trends for some parameters and loss of significance for trends in other parameters (Geomega 2004). As discussed below, the aquifer continues to adjust to the changes induced by the cessation of pumping. This period of adjustment was previously forecast to last from one to three years (Geomega 2003).

4.2 WBV Monitoring Wells

4.2.1 Sentinel Wells

Near the Chestnut Street wells, well GW-63D shows positive trends for all five parameters but no Shewhart or CUSUM exceedances. The sulfate data is typical of this well, showing stable concentrations, but at a level above the background mean high enough to produce a positive Kendall trend result, although not high enough to trigger control chart exceedances (Figure 2). Data from well GW-63S show positive trends for sodium, specific conductance, and sulfate, but, like well GW-63D, have no Shewhart or CUSUM control chart exceedances (Table 4). Control charts for the five parameters in GW-63S show stable recent concentrations (Figures 3 through 7). The stable concentrations in GW-63D and GW-63S suggest that the aquifer is stabilizing from the cessation of pumping but at concentrations generally higher than the background mean established while the Chestnut Street wells were pumping.

Near BR-1, well GW-64D displays negative concentration trends for all parameters except ammonia, which has no significant trend (Table 4). Concentrations in GW-64D are stable and below background mean values (Figures 8 through 12). Data from well GW-86M show negative trends for ammonia and sulfate (Table 4). This is a new trend for sulfate in this well (Figure 13). Data from well GW-86D do not contain any significant trends, however the specific conductance data does result in exceedances for Shewhart and CUSUM control charts (Table 4). The control charts indicate that an anomalous value recorded in the third quarter of 2003 is responsible for the exceedances (Figure 14).

Near BR-2, well GW-65S shows positive trends for chloride, and significant trends for sodium and specific conductance based upon control chart exceedances (Table 4). Well GW-65D indicates increasing trends in chloride, ammonia, sodium, and specific conductance, and both Shewhart and CUSUM exceedances for chloride and sodium (Table 4). Well GW-87D also has significant trends for all parameters except ammonia and Shewhart and CUSUM exceedances for specific conductance (Table 4). The control charts for specific conductance indicate an increasing trend (Figure 15).

In well GW-103D, positive trends and exceedances for both Shewhart and CUSUM exceedances were observed for chloride, sodium, specific conductance, and sulfate, with control chart exceedances occurring only with sodium (Table 4). The control chart exceedance for sodium is due to an anomalous concentration observed in the fourth quarter of 2004 (Figure 16).

The cessation of pumping in the Chestnut Street and Butters Row wells continues to have an effect on observed concentrations in the nearby Sentinel wells. Groundwater quality data suggest that the aquifer is still in the process of stabilizing following the discontinued groundwater withdrawals in the Wilmington WSWs.

4.2.2 Fate and Transport Wells

Near the Town Park well, data from well GW-73D shows decreasing concentration trends in chloride, sodium, and specific conductance, while an increasing trend continued for sulfate (Table 4). Corresponding Shewhart and CUSUM exceedances for sulfate were also observed (Figure 17).

In well GW-62S there was an increasing trend for ammonia with no corresponding control chart exceedance, a negative trend for sulfate, and a CUSUM exceedance for sodium without a significant Kendall trend (Table 4). In GW-62M increasing Kendall trends were noted for chloride, ammonia, and sodium. Shewhart and CUSUM exceedances were also detected for ammonia and sodium, a CUSUM exceedance for chloride, and a positive Kendall trend for specific conductance (Table 4).

Along the main axis of the WBV, well GW-83S shows increasing Kendall trends for chloride and sodium with corresponding control chart exceedances, and positive trends in ammonia and specific conductance without corresponding control chart exceedances (Table 4). Data from well GW-83M show positive trends and CUSUM exceedances for chloride and sulfate, trends and both Shewhart and CUSUM exceedances for sodium, a positive trend but no exceedances for specific conductance, and no trend and Shewhart and CUSUM exceedances for ammonia (Table 4). The data for ammonia show widely fluctuating values that produced the control chart exceedances, but the most recent concentration was close to background and the data did not generate a significant trend (Figure 18). Data from GW-83D show a trend in specific conductance with no control chart exceedances (Table 4).

Data from GW-84M show a positive trend for sodium and a negative trend for specific conductance, but no control chart exceedances. However, ammonia from GW-84M displays both Shewhart and CUSUM exceedances without a significant trend (Table 4). As with GW-83M, the ammonia data from GW-84M display wide fluctuations which produce the control chart exceedances without generating a trend (Figure 19). Data from GW-84D show new trends in both ammonia and specific conductance with CUSUM exceedances (Table 4). Both sets of control charts show recent data that is above historical background, but relatively stable (Figures 20 and 21). Data from GW-85D show no significant trends but do show CUSUM exceedances for ammonia and specific conductance (Table 4). The control charts for ammonia again display recently fluctuating concentrations that produce a control chart exceedance, but not a significant trend (Figure 22).

4.3 Bedrock Monitoring Wells

Significant increasing trends for ammonia were observed in GW-62BR and GW-65BR and a significant decreasing trend for sulfate was identified in GW-65BR. All parameters in GW-103BR displayed significant decreasing trends (Table 5).

The trend in ammonia from GW-62BR is dominated by an anomalously low concentration in the first sample of the series; most subsequent data are higher in concentration and exhibit little or no trend. However, recent data do show a consistent trend (Figure 23). The ammonia trend in GW-65BR consistently increased from 1995 through 2000, stabilized through 2002, and recently became positive (Figure 24). The declining sulfate trend in GW-65BR is dominated by an anomalous high concentration in the first sample of the series and has been stable in subsequent samples (Figure 25).

Historically in GW-103BR, the concentrations have fluctuated about a relatively stable value. Since 2003, however, concentrations of all five parameters have trended downward and remained stable (Figures 26 through 30). Given the timing and proximity of GW-103BR to the Chestnut Street wells, it is possible that the cessation of pumping has resulted in lowering the concentrations at this location.

4.4 Sanmina Supply Wells

Significant decreasing trends were again observed for ammonia and sulfate with an increasing trend in chloride in well B1, while increasing trends were again observed for chloride, sodium, and specific conductance in well B3. (There have been no new data compiled for sodium in B3 since September 2001.) The trends are attributed to a fundamental change in the Sanmina pumping regime, which was initiated by the reduction (essentially a shutdown) in pumping from B1 in mid-1999, and the subsequent increase in pumping rate at B3 (Figure 31). At the time of publication, the pumping rates from the Sanmina wells were only available through June 2004 (MACTEC 2005a).

The chemical trends in the Sanmina wells appear to correspond to changes in usage of the individual wells. Although chloride concentrations are showing a steady increase (Figure 32), concentrations of ammonia and sulfate in B1 drop in mid-1999 (Figures 33 and 34, respectively), at the same time that pumping from that well declines (Figure 31). The concentration of chloride and specific conductivity in B3 increased slightly during this time frame (Figures 35 and 36), when the B3 pumping rate was increased (Figure 31). Thus, the changes observed in the Sanmina well data appear to be pumping-rate induced, rather than indicating large-scale mobilization of the Olin plume in that area.

4.5 Surface Water Sampling Program

In the fourth quarter of 2003, a quarterly surface water monitoring plan was established for Maple Meadow Brook (MMB) and Sawmill Brook (SMB). The purpose of this monitoring plan is to establish a program that will allow for the quantitative evaluation of surface water quality within the MMB and SMB relative to Site-specific constituents of concern. As prescribed, during the period from fourth quarter 2003 through the fourth quarter 2004 five quarterly sampling events were completed at 11 surface water sampling locations (Figure 1). Although these new data contribute significantly to the surface water quality data that were collected prior to the fourth quarter 2003, the application of robust quantitative statistical methods remains temporarily limited. However, there is now sufficient data to begin to describe and compare sample population characteristics and to identify temporal and spatial variability in surface water quality in SMB and MMB. The ability to evaluate surface water quality with more rigorous quantitative methods will grow as additional quarterly data are collected.

4.5.1 Sawmill Brook and Maple Meadow Brook

The MMB and SMB flow from the south and south-southwest to the north-northeast through an extensive wetland area west of the Site. The headwaters of MMB extend to the south approximately 0.75 mile to Mill Pond Reservoir. The headwaters of SMB extend to the west-southwest approximately one mile and into an area of residential development. West-northwest of the Site the SMB and MMB join and flow north, serving as the headwaters of the Ipswich River. Peat and organic sediment thickness varies throughout the MMB and SMB wetlands and may be as great as 30 feet near the center of the wetlands (Geomega 2001).

Due to their close proximity to urban and residential areas, SMB and MMB (as well as the adjacent wetlands) are susceptible to water quality impacts from urban influences and road runoff upstream from and adjacent to the WBV. These potential impacts may include various effects from deicing road-salts, fertilizer use, and septic fields, as well as other point and non-point sources typically associated with urban and residential areas.

4.5.2 Precipitation

Precipitation is recorded daily at the Site. Precipitation is distributed with near uniformity throughout the year as rain from April through October and with snow dominant from November through March. Total recorded precipitation during the 15-month sampling period (fourth quarter 2003 through fourth quarter 2004) was 68.53 inches. During calendar year 2004, 55.49 inches of precipitation was recorded. For comparison, 50.46 inches and 53.48 inches of precipitation was recorded during calendar years 2003 and 2002, respectively. The most notable precipitation event during the sampling period was March 31 and April 1, 2004, during which 7.45 inches of precipitation was recorded at the Site. In addition, during November 12-13, 2004 (five days prior to the fourth quarter sampling event) the first significant snowfall of the season occurred (with over 6 inches of snow recorded in the area).

4.5.3 Stream Discharge

The closest continuously monitored surface water discharge gauging station within the Ipswich River watershed is located near South Middleton, MA (approximately 6 miles downstream from the confluence of MMB and SMB, USGS station No. 01101500). Calculated estimates of stream discharge within the MMB and SMB can be derived based upon a regression relationship developed using discharge data from MMB recorded during the period 1962-1974 and corresponding stream discharge data recorded from the Ipswich

River at South Middleton (Geomega 2001). Although this regression relationship may not represent subsequent localized or basin-wide hydrologic changes, the relative magnitude of temporal discharge fluctuations can be presented relative to recorded precipitation (Figure 37). Historically, the lowest sustained stream flow volumes are recorded during late summer and into the fall and winter. Most seasonal peak flows for MMB are calculated to be in the range of 10 to 30 cubic feet per second (cfs). Peak flows may be recorded following significant storm events at almost any time of the year, but generally occur during the spring. Snow and ice may persist for extended periods during the winter months.

4.5.4 Surface Water Analytical Results

The WBV surface water monitoring program includes 11 sampling locations within MMB and SMB (Figure 1). Five sampling locations are within SMB (SW-11, SW-8A, SW-8, SW-5 and SW-4). Four sampling locations are within MMB (SW-6, SW-2, SW-3, and SW-10). Two sampling locations (SW-1 and SW-9) are below the confluence of SMB and MMB. The following discussion concerns the five quarterly sampling events during the period from fourth quarter 2003 through the fourth quarter 2004.

As with the previous groundwater analyses, the primary water quality indicator parameters discussed in this section include chloride, ammonia (as nitrogen), sodium, sulfate, calcium, and specific conductance. Summary statistics for each of the surface water sampling locations and parameters are presented in Table 7. Concentration distributions (representing all historic data) for these six parameters at each MMB and SMB sample location are presented with box-plots in Figures 38 through 43 (a descriptive sample box-plot is presented in Figure 44). Analyte concentrations versus time (for the five quarters included during this sampling period) are presented in Figures 45 through 50. In addition, more detailed summary statistics are presented in Table 8. These detailed summary statistics include calculated confidence limits about the mean (for assumed normal and log-normal distributions) and median (assumed non-parametric) values. However, caution should be exercised interpreting and applying these preliminary calculations as these statistical summaries are based upon a limited number of data values (as few as four for some parameters and locations).

4.5.5 WBV Wetlands Hydrology

The hydrology and water chemistry of MMB and SMB within the WBV are influenced by the surrounding wetlands. Wetlands modify or alter many characteristics of streams, including stream slope, channel width, depth, flow velocity, discharge, sediment type, temperature, and nutrient and light regimes (Armstrong and Lent 1995). The MMB and SMB wetlands are typical of a wetland stream environment: a rich organic substrate (up to 30 feet in thickness), poorly defined channels, low flow gradients and velocities (resulting in increased residence times), less turbulent flow, reduced (and variable) dissolved oxygen (DO) concentrations, and variable oxidation-reduction (redox) conditions. Variable DO and redox conditions can have a significant effect on certain biochemical processes and on those corresponding constituents that are DO or redox sensitive.

The influence and impact of wetlands on adjacent stream water quality has been well documented. A study of water quality within selected wetland streams in central and eastern Massachusetts concluded that stream nutrient and DO conditions within wetlands can be quite variable and that wetlands can have a wide variety of effects on stream-water quality (Armstrong and Lent 1995). In addition, water-quality data collected by the Massachusetts Division of Water Pollution Control (MDWPC) indicate that dissolved-oxygen concentrations can decrease and nutrient concentrations can increase along stream reaches that are contiguous to wetland areas (Suurballe 1992).

4.5.6 Oxidation-Reduction (Redox)

Redox processes occur continuously in aquatic environments and can have a profound influence on the chemical composition of water (particularly upon redox-sensitive constituents). The hydrology of most wetlands environments supports a range of oxidizing and reducing conditions that can change over time and vary by location. These variable redox processes or conditions govern the occurrence, distribution and concentration of many solutes. In addition, redox conditions within surface waters can fluctuate daily, monthly, or seasonally, resulting in corresponding fluctuations in redox-sensitive water quality parameters, such as ammonia.

The principle and most common oxidizing agent in surface waters is oxygen. The oxygen content in water is quantified and expressed as DO and provides a general indication of aqueous redox conditions. Sources of DO include photosynthesis (oxygen productivity) and exchanges with the atmosphere at the water surface (aeration). Consumption of DO is caused by the respiratory processes of aquatic plants and aerobic bacteria, and chemical oxidation reactions (Suurballe 1992).

Redox was measured as a field parameter at the time of surface water sample collection. Redox measurements produce a numerical index of the relative intensity of oxidizing or reducing conditions. Negative values are indicative of relative reducing conditions and positive values represent relative oxidizing conditions. Redox measurements may be used to determine the likelihood of occurrence of a given redox process but can not be used to determine the concentrations of specific species, to isolate individual chemical reactions, or to determine the corresponding rates of oxidation or reduction (Artiola, et al 2004).

The majority of the measured redox values within SMB and MMB surface water ranged from approximately -50 millivolts to +150 millivolts (Figures 51a and 51b). These values reflect the influence of the reducing conditions present within the adjoining wetlands. Values of +350 to +550 millivolts are typically reported for oxygenated surface waters (Hem 1970). The presence of free dissolved oxygen in water produces values in the range of +400 to +700 millivolts and oxidation by oxygen occurs in the range of +400 to +600 millivolts (Mitsch and Gosselink 1993).

Location SW-8 recorded the greatest range of redox values (-72 to +205 millivolts). The lowest mean and median redox values were measured at locations SW-4 (in SMB above the confluence with MMB) and SW-6 (the farthest upstream sample location in MMB). The higher range redox values during the period were recorded at locations SW-11 and SW-9 (Figures 52a and 52b). The observed temporal fluctuations in redox values reflect variability in stream flow conditions, temperature, microbial activity and detritus decomposition.

In addition, the range of measured redox values is conducive to the occurrence of multiple redox-driven processes. These include the reduction of Fe^{+3} to Fe^{+2} as well as the oxidation of Fe^{+2}, the oxidation of sulfide to sulfate, the reduction of nitrate, and denitrification. The oxidation of ammonia to nitrate requires a redox potential of approximately +250 millivolts and is not likely to occur under the observed redox conditions in SMB and MMB.

Dissolved oxygen concentrations were also measured at the time of sample collection. The DO concentration in surface water is a dynamic indicator of the balance between oxygen-consuming and oxygen-producing processes at the moment of sample collection (Hem 1985). It is a highly transient property and represents conditions during only a brief period of time at the specific sampling location. Measured DO concentrations in MMB and SMB ranged from 1.88 mg/L to 15.43 mg/l. These concentration values were transformed to percent saturation (based upon the water temperature recorded at the time of sample collection) (Figures 53a and 53b).

Measured DO saturations in SMB during the period ranged from 14% (SW-5) to 130% (SW-8) of saturation (Figure 54b). Generally, the lowest values were recorded during the first and third quarters of 2003. This is consistent with reduced seasonal flow conditions during these periods. Measured DO in MMB ranged from 42% (SW-3) to 150% (SW-2) of saturation (Figure 54a).

Of note, during November 12-13, 2004 (five days prior to the fourth quarter sampling event) over 6 inches of snow was recorded in the area. The subsequent snowmelt would have produced increased runoff, thereby temporarily increasing (or temporarily sustaining) DO concentrations with an associated increase in oxidizing conditions.

4.5.7 Iron

Iron (Fe) is one of the most important redox-sensitive elements in the environment (Deutsch 1997). This redox-sensitivity allows aqueous iron concentrations to be used in the evaluation of relative redox conditions. Under oxidizing (i.e. higher DO) conditions elemental Fe is oxidized to Fe(+2) and the insoluble form Fe(+3). Under reducing conditions (i.e., lower DO) Fe may be present as a stable and more soluble species. Consequently, iron concentrations may serve as a useful surrogate indicator of redox conditions.

The MMB and SMB surface water sampling program has included laboratory analyses for dissolved (soluble) Fe (Figure 55) and field measurements of DO and redox. Dissolved Fe concentrations in MMB and SMB surface water would be expected to respond to the variable stream flow and DO conditions (increasing with reduced DO concentrations and decreasing with increased DO concentrations). Observed fluctuations in dissolved Fe concentrations can often be correlated to fluctuations in concentrations of other redox sensitive parameters (such as ammonia).

4.5.8 Ammonia

Ammonia is a naturally-occurring nitrogen species that may be produced in abundance within wetland environments. In fact, the production of dissolved ammonia from the breakdown of organic nitrogen (ammonification) is the principle source of ammonia in most aquatic systems (Suurballe 1992). Wetland systems (such as those through which MMB and SMB flow) provide an abundant source of nitrogen rich organic material available for decomposition. Degradation and decomposition cycles generally follow a seasonal pattern coinciding with the cessation of plant growth. As a result, ammonia production (and hence, aqueous concentrations) would most likely be observed to increase during those times of the year when plant decomposition is greatest (which often coincides with reduced stream flow conditions). In addition, DO concentrations in water may govern the species of nitrogen (nitrate, ammonia, etc.) transported from wetland areas (Suurballe 1992). Low DO concentrations would indicate favorable conditions for the transport of ammonia while higher DO levels would favor nitrate transport.

4.5.9 Ammonia Results

As expected, SMB and MMB surface water ammonia concentrations display varying degrees of spatial and temporal variability. Although seasonal data is limited at this point in time, ammonia concentrations appear to reflect expected seasonal hydrologic and biochemical influences. Observed ammonia concentrations are generally greatest during periods of reduced stream flow, depressed DO concentrations, and increased decomposition of organic material. Lower ammonia concentrations have generally been observed during periods coinciding with increased stream flow and elevated DO concentrations and plant growth. (Figures 45a and 45b). Most of the measured ammonia concentrations in SMB and MMB during the period are less than 1.0 mg/L. This is relatively consistent with the range of surface water ammonia concentrations reported for the Ipswich River Basin (Campo et al. 2003). The highest concentrations during this sampling period were reported at locations SW-3 (2.2 mg/L) and SW-11 (1.88 mg/L). Both of these values were recorded during or following seasonal periods of low stream flow (late-summer and mid-winter, respectively) and are consistent with reduced DO conditions.

Consistent with a wetlands environment, SMB and MMB ammonia concentrations also vary by location. A graphical display of this spatial variability is shown in Figures 38a and 39a. Within SMB the highest historical mean and median ammonia concentrations have been measured at location SW-11 (the farthest upstream sample location). The greatest historical range of ammonia concentrations in SMB is at location SW-4 followed by location SW-11. All historic mean and median concentration values at SMB sample locations are below 1.0 mg/L.

Within MMB the greatest historical variability in ammonia concentrations occurs at location SW-6 (the farthest upstream location) followed by location SW-3 (Figure 39a). The majority of the ammonia concentrations within MMB throughput the period were below 1.0 mg/L. Historic mean and median ammonia concentrations generally decrease from upstream to downstream sample locations. This is likely due to local variability in wetlands characteristics and/or increased stream flow within this reach.

In order to relate the observed variability in ammonia concentrations to aquatic redox conditions, iron concentrations were examined at four representative sample locations (SW-1, SW-5, SW-2 and SW-11) (Figures 56 and 57). The observed fluctuations in ammonia and iron concentrations behave as expected and are consistent with variable (seasonal) redox conditions. If ammonia concentrations in SMB or MMB were consistently behaving counter to a redox-driven model, then additional sources of ammonia could be indicated. Additional quarterly sampling data will provide the information needed to further correlate temporal and spatial redox effects relative to ammonia concentrations.

The observed temporal and spatial variability in surface water ammonia concentrations are consistent with the expected variability within a dynamic wetlands environment. There is no indication at the time of this report that surface water ammonia concentrations are exhibiting anomalous trends or behaviors.

4.5.10 Sulfate

Organic-sulfur compounds are common is wetland sediments. Sulfur occurs in a variety of oxidation states and its behavior is strongly related to the redox conditions of aqueous systems. (Hem 1985). In natural waters, sulfate is the major oxidized form of sulfur and sulfide is the major reduced form. Sulfate concentrations within wetland waters have been shown to be governed by the amount of DO present in the water and the residence time of water within wetlands (Suurballe 1992).

4.5.11 Sulfate Results

Similar to ammonia, sulfate concentrations exhibited varying degrees of temporal and spatial variability (although the degree of variability is slightly less than that of ammonia). The majority of sulfate concentrations within SMB during the period ranged from less than 10 mg/L to less than 20 mg/L. (Figures 46a and 46b). Historic median sulfate concentrations in SMB decrease slightly from upstream to downstream locations (Figure 38b).

Historic mean and median sulfate concentrations within MMB are similar to SMB. Most MMB sulfate concentrations are less than 20 mg/L (Figure 39b). Locations SW-6 and SW-3 display the greatest range in concentrations. Generally, sulfate concentrations within SMB and MMB appear well behaved and unremarkable.

The range of sulfate concentrations in MMB and SMB is consistent with sulfate concentrations reported for selected rivers in the New England coastal basin (Campo et al. 2001) and selected wetland streams in Massachusetts (Armstrong and Lent 1995). There is no indication that surface water sulfate concentrations are exhibiting anomalous trends or behaviors during this reporting period.

4.5.12 Chloride, Sodium, Calcium, and Specific Conductance

Chloride, sodium and calcium occur naturally in aquatic environments. These three constituents also form the principle components of deicing road-salt. The use of road salt as a deicer on roads in Massachusetts is common during the winter months. In fact, Massachusetts reports one of the highest rates of annual road-salt loadings (NRC 1991). The most common form of road-salt is a sodium-chloride (NaCl) mixture. A calcium-chloride (CaCl) mix is used in some locations or under colder conditions. Correlations have long been established linking road salt to elevated chloride concentrations in surface waters. The correlation is weakest for large rivers because of the large dilution factor associated with river discharge volume. Generally, smaller streams and creeks are more likely to be affected. The magnitude of the impact depends on factors such as water flow, salting intensity, precipitation, type of highway drainage system, topography, and natural drainage patterns (NRC 1991).

4.5.13 Chloride, Sodium, Calcium and Specific Conductance Results

A strong covariance has been described between concentrations of the dissolved constituents of road-salt (e.g. sodium, chloride) and specific conductance (SC) in selected Massachusetts highway runoff samples (Granato and Smith 1999). Concentrations of sodium, chloride, and SC across all MMB and SMB surface water samples also reveal a strong covariance but little correlation with calcium concentrations (Figure 58). As both the MMB and SMB are susceptible to water quality impacts from road-salt run-off, this suggests the dominant use of a NaCl road-salt mixture on area roadways. In addition, the ratio of Cl:Na concentrations within MMB and SMB surface water samples is relatively consistent across all sample locations and sample periods (with mean ratios approximately 1.5 to 1.9) while Cl:Ca concentration ratios exhibit a much greater degree of variability (mean ratios ranging from approximately 2.6 to over 9.0). This further supports a strong sodium-chloride relationship.

As previously mentioned, on November 12-13, 2004 (five days prior to the fourth quarter sampling event) over 6 inches of snow fell in the area. The subsequent snowmelt would have lead to localized increases in storm water runoff and the introduction of road-salt-related constituents into receiving waterways. The effects of this storm event are evident in the chloride, sodium and SC results from the fourth quarter 2004 (Figures 47, 48 and 49). Concentrations of these parameters display sharp increases at several sampling locations (e.g. SW-11, SW-8A, and SW-5).

Temporal and spatial variability in chloride concentrations is evident in SMB and MMB surface water quality data (Figures 40a, 41a, and 47). Within MMB the lowest mean and median chloride concentrations for the recent period were at location SW-6 (the farthest upstream sample location within MMB). The highest historic mean and median chloride concentrations were at location SW-10 (just above the confluence with SMB). As expected, sodium concentrations show a similar behavior (Figure 41b). Historic calcium concentrations are unremarkable and decrease slightly along this MMB reach and are within the range of concentrations reported in SMB.

Chloride concentrations in SMB varied significantly at some locations during the period. The greatest variability was associated with locations SW-11, SW-8A, and SW-5 (Figure 40a). As expected, similar patterns exist in the specific conductance and sodium data (Figures 40b, 42b, 51b and 52b). Within SMB, the highest mean chloride concentration for the period was recorded at location SW-11 (760 mg/L). It is strongly suggested that these elevated sodium, chloride, and specific conductance values reflect an influx of road salt into SMB from an upstream road crossing or highway drainage (e.g. Chestnut Street). Historic calcium concentrations appear stable along this reach of SMB (Figure 42a) with concentration ranges similar to those in MMB (Figure 43a).

In addition, the historic median chloride concentrations recorded within SMB are approximately 30% greater than in MMB and the historic mean chloride concentrations within SMB are approximately 85% greater than in MMB (Figures 40a and 41a). This suggests that the closer proximity of SMB to upstream roadways (or other sources) is having a more significant and noticeable impact on water quality. Within SMB, the historic mean and median concentrations of chloride and sodium generally decrease from upstream to downstream (consistent with possible dilution effects). The opposite is the case in MMB with historic mean and median values increasing slightly from upstream (SW-6) to downstream (SW-10).

Specific conductance values within MMB during the period ranged from approximately 200 µmhos/cm to 900 µmhos/cm (Figure 49a). The highest values were recorded during the first and fourth quarters of 2004 and follow similar patterns in chloride and sodium concentrations. Specific conductance values within SMB were similar to MMB except for much higher values recorded at some sample locations during the fourth quarter 2004 (notably, SW-11, SW-8A and SW-5) (Figure 49b). This pattern is consistent with the observed concentrations of chloride and sodium at these locations and the effects of a snow storm event five days prior to sample collection.

Water quality data from MMB and SMB suggest that there are pronounced road-salt impacts to surface water quality, especially within SMB. These transient water quality impacts can be expected to persist with potentially significant variability.

4.6 Considerations for the MMBA Monitoring Plan

The information and results presented in this evaluation report support the continuation of the MMBA monitoring plan without modification (although limited changes supporting the statistical methods may be warranted). Specifically:

- Concentrations of indicator parameters in the Sentinel wells near the WSWs appear to be stabilizing, while concentrations in wells in the WBV are exhibiting minor fluctuations. Although the monitoring well network continues to serve as a functional indicator of groundwater quality and of the dynamic behavior of the COC plume, modifications to the background data window used to calculate statistical limits may be warranted in order to continue to provide a reliable monitoring program.

- Concentrations in well GW-103BR (near the Chestnut Street wells) have dropped and appear to be stabilizing in response to the cessation of pumping. Data and trends from wells GW-62BR and GW-65BR are consistent with previous analyses.

- Concentrations in the Sanmina supply wells continued to vary with pumping rates, but did not reflect significant changes or large-scale mobilization of the local COC plume.

- Data collected from the Sentinel well monitoring program will continue to be incorporated into the statistical tests used to assess the stability of or temporal changes in groundwater solute concentrations. Screening of quarterly data based upon these statistical analyses will result in decisions requiring no further action, data verification, or some other action. If required, verification resampling will be performed within one month after a statistical exceedance has been identified. If an exceedance is verified through resampling, MADEP will be consulted and a consensual response developed.

- This groundwater monitoring period reflects a transition to post-pumping conditions. The changes in aquifer conditions related to the cessation of pumping from the

WSWs may necessitate a re-examination of the data sets used to calculate background condition statistical limits. Groundwater quality data collected following the cessation of pumping may be used to form the basis of new statistical limits. These new calculated limits could provide a more representative baseline for future statistical comparisons.

- The quarterly sampling data from the surface water monitoring network show pronounced temporal (seasonal) variability in select monitoring parameters. This variability is associated with those parameters most sensitive to redox conditions. If the observed magnitude of this seasonal variability continues, additional quarterly monitoring data will be required to provide sufficient data to incorporate this variability into robust statistical analyses. In addition, water quality impacts from deicing road-salt runoff (NaCl) are indicated within the Sawmill Brook and the Maple Meadow Brook.

- Based on the observed fluctuations in groundwater quality, the temporal and spatial variability of surface water quality, and the potential need to further relate surface and groundwater chemistry, continued sample collection under the requirements of the current MMBA monitoring program will provide the data and information necessary for future statistical analyses. Modifications and enhancements to future statistical comparisons are currently being considered to appropriately accommodate expected and ongoing changes in aquifer condition while providing the ability to detect anomalous or adverse changes in groundwater and surface water quality.

5 Conclusions

The following conclusions are based upon the results of the quantitative and qualitative analyses presented in this evaluation report:

1. During 2003 pumping at the Wilmington WSWs ceased. This has resulted in a stabilization of concentrations in most of the Sentinel wells. However, deep wells in the WBV showed fluctuations in concentrations for selected constituents.

2. Data collected during the June 2003 to December 2004 monitoring period supports Geomega's previous finding that the pumping of the WSWs affected solute concentrations in the Sentinel wells and perhaps the wells in the WBV.

3. Bedrock monitoring wells in the WBV are showing some increasing trends, although close examination of the data reveals that the concentrations are currently stable and that the calculated trends are the result of historical concentrations observed early in the sampling history of those wells. An exception is well GW-103BR which is showing a decrease in concentrations associated with the cessation of pumping at Chestnut Street.

4. The Sanmina wells are showing changes in concentrations of the five parameters considered in the statistical analyses, which reflect changes in the pumping regime at that facility rather than indicating large-scale mobilization of the plume.

5. Indicator solute concentrations in selected wells may be stabilizing relative to baselines that reflect predicted changes in aquifer conditions following the cessation of WSW pumping. As such, this groundwater monitoring period reflects a transition to post-pumping conditions. During this transition or stabilization period, results from the statistical analyses should be treated cautiously, because apparent changes in solute concentrations could be misinterpreted to indicate significant mobilization of Site-related constituents. Modifications to future statistical comparisons are currently being considered to appropriately address these expected and ongoing changes in aquifer condition.

6. As prescribed, during the period from fourth quarter 2003 through the fourth quarter 2004 five quarterly sampling events were completed at 11 surface water sampling locations. Although these new data contribute significantly to the amount of surface water quality data, the data set is insufficient for the application of robust quantitative statistical methods. However, there is now sufficient data to begin to describe and compare sample population characteristics and to describe temporal and spatial variability in surface water quality in SMB and MMB. The ability to evaluate surface water quality with more rigorous quantitative methods will grow as additional quarterly data are collected.

7. The hydrology and water chemistry of MMB and SMB within the WBV are influenced by the surrounding wetlands. The hydrology of most wetlands

environments supports a wide range of oxidizing and reducing (redox) conditions that can change dramatically over time and vary by location. These variable redox processes or conditions govern the occurrence, distribution and concentration of many solutes. Temporal and spatial variability in solute concentrations can be significant within wetlands environments. Varying degrees of this predicted variability have been noted throughout SMB and MMB and should be expected to continue.

8. Ammonia is a naturally-occurring nitrogen species that may be produced in abundance within wetland environments. In addition, ammonia is sensitive to redox conditions which can result in significant variability in concentrations. Observed concentrations of ammonia in SMB and MMB during the period reflect this variability. If ammonia concentrations in SMB or MMB were consistently behaving counter to a redox-driven model, then additional sources of ammonia could be indicated. There is no indication that surface water ammonia concentrations are exhibiting anomalous trends or behaviors. However, temporal variability in ammonia concentrations can be expected to continue throughout the WBV wetlands. The majority of ammonia concentrations measured during this period in SMB and MMB were below 1.0 mg/L.

9. Pronounced road-salt impacts to surface water quality (elevated sodium and chloride concentrations) are evident, especially within SMB. Concentrations of sodium, chloride, and specific conductance across all MMB and SMB surface water samples reveal a strong covariance. There is little correlation with calcium concentrations. As both the MMB and SMB are susceptible to water quality impacts from highway run-off, this suggests the dominant use of a NaCl road-salt mixture on area roadways.. These transient water quality impacts within SMB and MMB can be expected to persist with potentially significant variability.

10. Organic-sulfur compounds are common is wetland sediments. Sulfur occurs in a variety of oxidation states and its behavior is strongly related to the redox conditions of aqueous systems. Generally, sulfate concentrations within SMB and MMB appear well behaved and unremarkable and there is no indication that surface water sulfate concentrations are exhibiting anomalous trends. Observed sulfate concentrations (generally 10 to 20 mg/L) are within the range of values reported for the Ipswich River basin and are consistent with normal range seasonal fluctuations.

11. The information and results presented in this evaluation report support the continuation of the MMBA groundwater and surface water monitoring plan without modification. Ongoing groundwater and surface water quality data collection efforts will contribute to the characterization needs and monitoring requirements of the Western Bedrock Valley monitoring program.

6 References

Armstrong, David S., Lent, Robert M, 1995. Water Quality in Selected Wetland Streams in Central and Eastern Massachusetts, 1988-89. Water-Resources Investigations Report 95-4157: US Geological Survey.

Artiola, Janick F., Pepper, Ian L., Brusseau, Mark L., eds. 2004. *Environmental Monitoring and Characterization*. Amsterdam: Elsevier Academic Press.

Campo, Kimberly W., Flanagan, Sarah M., Robinson, Keith W., 2003, Water Quality of Selected Rivers in the New England Coastal Basins in Maine, Massachusetts, New Hampshire, and Rhode Island, 1998-2000. Water-Resources Investigations Report 03-4210. Pembroke, NH: US Geological Survey

Deutsch, William J., 1997. *Groundwater Geochemistry: Fundamentals and Applications to Contamination*. Boca Raton: Lewis Publishers.

Geomega. 1998. A statistical analysis of water quality trends in the Maple Meadow Brook Aquifer and proposed modifications to the Western Bedrock Sentinel Well program. Olin Wilmington Technical Series: II (September 1998). Boulder, CO: Geomega Inc.

Geomega. 2000. A statistical analysis of water quality trends in the Maple Meadow Brook Aquifer. Olin Wilmington Technical Series: XII (October 2000). Boulder, CO: Geomega Inc.

Geomega, 2001. A Groundwater Flow and Solute Transport Model for the Olin Corporation Site (RTN: 3-0471) in Wilmington, Massachusetts (4/27/01). Boulder, CO, Geomega, Inc.

Geomega. 2003. Technical Memorandum: Review of Maple Meadow Brook surface water sampling program (August 20, 2003). Boulder, CO: Geomega Inc.

Geomega. 2004. The 2003 Western Bedrock Valley statistical report. Olin Wilmington Technical Series: XXXIII (May 2004). Boulder, CO: Geomega Inc.

Gibbons, R.D., Coleman, D.E., 2001. *Statistical Methods for Detection and Quantification of Environmental Contamination*. New York: John Wiley and Sons.

Gibbons, R.D., 1999. Use of Combined Shewhart-CUSUM Control Charts for Ground Water Monitoring Applications. *Ground Water*. 37 (5):682-691.

Gibbons, R.D. 1994. *Statistical Methods for Groundwater Monitoring*. New York: John Wiley & Sons.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. New York: Van Nostrum Reinhold.

Granato, Gregory E., Smith, Kirk P., 1999. Estimating Concentrations of Road-Salt Constituents in Highway-Runoff from Measurements of Specific Conductance. Water-Resources Investigations Report 99-4077. Northborough, MA: US Geological Survey

Hem, John D., 1985. Study and Interpretation of the Chemical Characteristics of Natural Water, (3d ed). Water-Supply Paper 2254. Alexandria, VA: US Geological Survey.

Hem, John D., 1970. Study and Interpretation of the Chemical Characteristics of Natural Water, (2d ed.). Water-Supply Paper 1473. Washington D.C.: US Geological Survey.

MACTEC. 2005a. Western Bedrock Valley ground-water monitoring report, June 2003 – December 2004 (June 2005). Wakefield, MA: MACTEC Engineering and Consulting Inc.

MACTEC. 2005b. Maple Meadow Brook Surface Water Interim Data Summary. To: Mr. Christopher Pyott (MADEP). August 2005. MADEP. Wakefield, MA: MACTEC Engineering and Consulting Inc.

Millard, S.P. 2002. EnvironmentalStats for S-Plus (software). Seattle: Probability, Statistics & Information.

Mitsch, William J., Gosselink, James, G. 1993. *Wetlands (3d ed.).* New York: John Wiley and Sons.

National Research Council (NRC), 1991. Transportation Research Board. *Highway Deicing: Comparing Salt and Calcium Magnesium Acetate.* Special Report 235.

Starks, T.H. 1989. Evaluation of control chart methodologies for RCRA waste sites. EPA/600/4-88/040. Las Vegas: US Environmental Protection Agency.

Suurballe, Nancy C., 1992. Effects of a Wetland on Quality of Natty Pond Brook. Massachusetts, 1985-1986. Water-Resources Investigations Report 91-4144. Marlborough, MA: U.S. Geological Survey.

US EPA. 1989. Statistical analysis of ground-water monitoring data at RCRA facilities: Interim final guidance. EPA/530/SW/89/026. Washington, DC: US Environmental Protection Agency.

US EPA. 1992. Statistical analysis of ground-water monitoring data at RCRA facilities: Addendum to interim final guidance. Washington, DC: US Environmental Protection Agency.

Whitman and Howard. 1974. Report relative to water quality, Wilmington, Massachusetts. Prepared for the Board of Water and Sewer Commissioners. Whitman and Howard Inc.

Tables

Table 1. Results of the Shapiro-Wilk Normality Tests
(Bold Italics Indicate Lognormal Data)

						Normal		Lognormal	
Location	**Parameter**	**N**	**%BDL**	**Slope**	**z**	**W**	**p**	**W**	**p**
GW-62D	Chloride	24	0	-0.109	-0.198	0.951	0.291	0.972	0.724
GW-62D	Nitrogen, Ammonia	24	0	0.035	1.564	0.501	0.000	0.806	0.000
GW-62D	Sodium, Dissolved	22	0	0.084	0.339	0.936	0.162	0.940	0.200
GW-62D	Specific Conductance	23	0	-0.045	0.000	0.773	0.000	0.477	0.000
GW-62D	Sulfate as SO4	24	0	-1.156	-1.612	0.963	0.511	0.978	0.849
GW-62M	***Chloride***	***21***	***0***	***1.474***	***3.412***	***0.905***	***0.043***	***0.923***	***0.099***
GW-62M	Nitrogen, Ammonia	22	0	0.042	3.615	0.955	0.390	0.923	0.086
GW-62M	Sodium, Dissolved	20	0	0.503	3.475	0.800	0.001	0.860	0.008
GW-62M	Specific Conductance	21	0	4.979	1.450	0.847	0.004	0.554	0.000
GW-62M	Sulfate as SO4	21	0	0.055	0.181	0.862	0.007	0.900	0.035
GW-62S	Chloride	24	0	0.063	0.223	0.978	0.851	0.989	0.993
GW-62S	Nitrogen, Ammonia	24	0	0.060	2.755	0.930	0.095	0.952	0.296
GW-62S	Sodium, Dissolved	22	0	0.083	0.480	0.935	0.157	0.964	0.574
GW-62S	Specific Conductance	23	0	-1.944	-1.400	0.700	0.000	0.440	0.000
GW-62S	***Sulfate as SO4***	***23***	***0***	***-0.654***	***-3.222***	***0.910***	***0.042***	***0.962***	***0.495***
GW-63D	***Chloride***	***29***	***0***	***2.604***	***3.569***	***0.896***	***0.008***	***0.973***	***0.640***
GW-63D	***Nitrogen, Ammonia***	***27***	***0***	***0.093***	***4.129***	***0.527***	***0.000***	***0.918***	***0.035***
GW-63D	Sodium, Dissolved	27	0	1.970	4.066	0.929	0.064	0.955	0.276
GW-63D	Specific Conductance	29	0	13.381	2.383	0.802	0.000	0.916	0.024
GW-63D	***Sulfate as SO4***	***29***	***0***	***1.293***	***1.013***	***0.760***	***0.000***	***0.956***	***0.261***
GW-63S	***Chloride***	***26***	***0***	***1.500***	***2.140***	***0.845***	***0.001***	***0.946***	***0.191***
GW-63S	***Nitrogen, Ammonia***	***27***	***22***	***0.018***	***2.296***	***0.615***	***0.000***	***0.888***	***0.021***
GW-63S	***Sodium, Dissolved***	***27***	***0***	***1.417***	***3.462***	***0.912***	***0.025***	***0.957***	***0.316***
GW-63S	***Specific Conductance***	***28***	***0***	***9.536***	***2.509***	***0.754***	***0.000***	***0.961***	***0.361***
GW-63S	***Sulfate as SO4***	***25***	***0***	***0.114***	***0.187***	***0.591***	***0.000***	***0.948***	***0.222***
GW-64D	Chloride	31	0	-0.429	-0.680	0.881	0.002	0.926	0.034
GW-64D	***Nitrogen, Ammonia***	***29***	***0***	***0.139***	***1.069***	***0.914***	***0.022***	***0.948***	***0.167***
GW-64D	***Sodium, Dissolved***	***29***	***0***	***-0.279***	***-0.169***	***0.898***	***0.009***	***0.933***	***0.065***
GW-64D	Specific Conductance	31	0	-5.000	-0.391	0.967	0.434	0.975	0.666
GW-64D	***Sulfate as SO4***	***31***	***0***	***-2.571***	***-0.918***	***0.857***	***0.001***	***0.961***	***0.311***
GW-65D	Chloride	21	0	0.566	2.209	0.957	0.450	0.949	0.330
GW-65D	Nitrogen, Ammonia	18	6	0.008	1.404	0.956	0.559	0.960	0.625
GW-65D	Sodium, Dissolved	19	0	0.189	0.562	0.960	0.568	0.958	0.529
GW-65D	Specific Conductance	21	0	6.000	2.236	0.893	0.025	0.794	0.001
GW-65D	Sulfate as SO4	21	0	0.417	0.242	0.975	0.846	0.920	0.086

Table 1 (cont.). Results of the Shapiro-Wilk Normality Tests

(Bold Italics Indicate Lognormal Data)

						Normal		Lognormal	
Location	**Parameter**	**N**	**%BDL**	**Slope**	**z**	**W**	**p**	**W**	**p**
GW-65S	Chloride	18	0	2.667	3.146	0.963	0.653	0.969	0.773
GW-65S	Nitrogen, Ammonia	18	0	0.057	1.138	0.971	0.814	0.923	0.145
GW-65S	Sodium, Dissolved	18	0	0.925	2.584	0.878	0.024	0.943	0.323
GW-65S	Specific Conductance	18	0	11.556	2.727	0.782	0.001	0.306	0.000
GW-65S	Sulfate as SO4	18	6	0.972	0.618	0.878	0.030	0.960	0.633
GW-73D	Chloride	27	0	-0.706	-1.650	0.935	0.090	0.911	0.024
GW-73D	Nitrogen, Ammonia	27	37	0.006	2.643	0.938	0.297	0.833	0.006
GW-73D	Sodium, Dissolved	26	0	-0.284	-1.703	0.952	0.256	0.973	0.689
GW-73D	Specific Conductance	27	0	-2.667	-1.709	0.971	0.626	0.963	0.436
GW-73D	Sulfate as SO4	27	0	0.131	1.253	0.946	0.170	0.976	0.774
GW-83D	Chloride	10	0	81.875	0.179	0.937	0.521	0.977	0.945
GW-83D	Nitrogen, Ammonia	10	0	-48.000	-0.894	0.955	0.725	0.853	0.064
GW-83D	Sodium, Dissolved	10	0	5.000	0.090	0.584	0.000	0.417	0.000
GW-83D	Specific Conductance	12	0	1215.909	0.480	0.578	0.000	0.846	0.033
GW-83D	Sulfate as SO4	10	0	700.000	0.808	0.867	0.092	0.698	0.001
GW-83M	Chloride	12	0	2.861	1.585	0.922	0.306	0.930	0.384
GW-83M	Nitrogen, Ammonia	12	0	-0.393	-1.050	0.778	0.005	0.683	0.001
GW-83M	Sodium, Dissolved	13	0	2.838	2.745	0.870	0.052	0.798	0.006
GW-83M	Specific Conductance	13	0	-3.050	-0.122	0.867	0.048	0.882	0.076
GW-83M	Sulfate as SO4	12	0	-0.733	-0.207	0.798	0.009	0.854	0.041
GW-83S	Chloride	10	0	1.500	1.252	0.896	0.198	0.858	0.073
GW-83S	***Nitrogen, Ammonia***	***11***	***0***	***0.216***	***2.335***	***0.809***	***0.012***	***0.935***	***0.465***
GW-83S	Sodium, Dissolved	11	0	1.789	2.180	0.977	0.946	0.962	0.799
GW-83S	Specific Conductance	11	0	11.333	1.868	0.785	0.006	0.812	0.014
GW-83S	Sulfate as SO4	10	0	1.700	0.988	0.710	0.001	0.795	0.013
GW-84D	Chloride	18	0	6.416	0.227	0.961	0.612	0.888	0.035
GW-84D	Nitrogen, Ammonia	17	0	5.926	1.689	0.946	0.399	0.410	0.000
GW-84D	Sodium, Dissolved	16	0	8.394	0.633	0.879	0.037	0.706	0.000
GW-84D	Specific Conductance	18	0	54.444	0.379	0.924	0.154	0.701	0.000
GW-84D	Sulfate as SO4	18	0	42.500	0.758	0.907	0.077	0.531	0.000
GW-84M	Chloride	17	0	-1.246	-1.701	0.735	0.000	0.636	0.000
GW-84M	Nitrogen, Ammonia	17	24	0.030	1.525	0.917	0.229	0.901	0.138
GW-84M	Sodium, Dissolved	16	0	0.866	2.026	0.945	0.413	0.923	0.188
GW-84M	Specific Conductance	18	0	-5.143	-2.772	0.799	0.001	0.729	0.000
GW-84M	Sulfate as SO4	17	0	-0.208	-1.072	0.904	0.078	0.936	0.278

Table 1 (cont.). Results of the Shapiro-Wilk Normality Tests

(Bold Italics Indicate Lognormal Data)

						Normal		Lognormal	
Location	**Parameter**	**N**	**%BDL**	**Slope**	**z**	**W**	**p**	**W**	**p**
GW-85D	Chloride	18	0	-2.929	-0.606	0.929	0.185	0.808	0.002
GW-85D	Nitrogen, Ammonia	18	0	-0.650	-1.253	0.802	0.002	0.492	0.000
GW-85D	Sodium, Dissolved	17	0	-5.036	-0.742	0.899	0.065	0.796	0.002
GW-85D	Specific Conductance	18	0	-95.833	-2.348	0.936	0.244	0.900	0.058
GW-85D	Sulfate as SO4	18	0	-33.636	-2.273	0.985	0.987	0.952	0.459
GW-85M	Chloride	17	0	3.171	0.783	0.581	0.000	0.766	0.001
GW-85M	Nitrogen, Ammonia	18	0	0.112	0.265	0.819	0.003	0.767	0.001
GW-85M	***Sodium, Dissolved***	***17***	***0***	***3.056***	***1.195***	***0.800***	***0.002***	***0.926***	***0.185***
GW-85M	Specific Conductance	18	0	0.444	0.000	0.712	0.000	0.866	0.015
GW-85M	Sulfate as SO4	17	0	1.272	0.165	0.558	0.000	0.878	0.030
GW-86D	Chloride	24	0	-2.704	-0.918	0.964	0.520	0.717	0.000
GW-86D	Nitrogen, Ammonia	25	0	0.385	1.122	0.842	0.001	0.488	0.000
GW-86D	Sodium, Dissolved	25	0	-4.226	-1.708	0.932	0.095	0.754	0.000
GW-86D	Specific Conductance	24	0	-52.302	-2.382	0.911	0.037	0.663	0.000
GW-86D	Sulfate as SO4	24	0	-15.313	-2.158	0.894	0.016	0.474	0.000
GW-86M	Chloride	24	0	0.023	0.074	0.810	0.000	0.934	0.117
GW-86M	Nitrogen, Ammonia	23	0	-0.076	-3.146	0.254	0.000	0.692	0.000
GW-86M	Sodium, Dissolved	23	0	0.000	0.027	0.807	0.000	0.884	0.012
GW-86M	Specific Conductance	23	0	-1.400	-0.582	0.801	0.000	0.885	0.012
GW-86M	***Sulfate as SO4***	***24***	***0***	***-0.520***	***-1.043***	***0.822***	***0.001***	***0.947***	***0.234***
GW-86S	Chloride	16	0	7.613	3.065	0.522	0.000	0.855	0.016
GW-86S	Nitrogen, Ammonia	15	0	0.047	1.342	0.337	0.000	0.564	0.000
GW-86S	Sodium, Dissolved	15	0	2.660	3.101	0.369	0.000	0.571	0.000
GW-86S	Specific Conductance	16	0	5.867	1.082	0.392	0.000	0.565	0.000
GW-86S	Sulfate as SO4	16	0	-6.599	-3.065	0.453	0.000	0.914	0.136
GW-87D	Chloride	16	0	25.970	2.026	0.980	0.966	0.461	0.000
GW-87D	Nitrogen, Ammonia	17	0	-0.052	-0.165	0.913	0.112	0.751	0.000
GW-87D	Sodium, Dissolved	17	0	9.288	1.900	0.978	0.937	0.964	0.712
GW-87D	Specific Conductance	17	0	51.250	1.857	0.844	0.009	0.853	0.012
GW-87D	Sulfate as SO4	16	0	49.126	1.850	0.970	0.844	0.897	0.071
GW-103D	***Chloride***	***16***	***0***	***2.729***	***3.884***	***0.885***	***0.046***	***0.949***	***0.472***
GW-103D	Nitrogen, Ammonia	17	65	NA	NA	NA	NA	NA	NA
GW-103D	***Sodium, Dissolved***	***16***	***0***	***0.888***	***3.755***	***0.834***	***0.008***	***0.891***	***0.059***
GW-103D	Specific Conductance	17	0	8.875	2.183	0.792	0.002	0.861	0.016
GW-103D	Sulfate as SO4	16	0	0.326	0.721	0.604	0.000	0.777	0.001

Table 2. Results of the Shewhart/CUSUM Control Chart Tests

		Background Statistics									
				Normal		Lognormal		Shewhart			
Location	Parameter	N	%BDL	Mean	SD	Mean	SD	UPCL[1]	Max	Exceedance	Units
GW-62D	Chloride	24	0	71.02	14.32	NA	NA	135.48	110	Y(C)	mg/l
GW-62D	Nitrogen, Ammonia	24	0	3.51	2.55	NA	NA	14.99	14.75	N	mg/l
GW-62D	Sodium, Dissolved	22	0	44.38	7.25	NA	NA	77.02	58	Y(C)	mg/l
GW-62D	Specific Conductance	23	0	470.60	109.75	NA	NA	964.46	610	N	umhos/cm
GW-62D	Sulfate as SO4	24	0	73.22	22.37	NA	NA	173.88	120.33	N	mg/l
GW-62M	Chloride	21	0	NA	NA	3.76	0.24	126.38	105	Y(C)	mg/l
GW-62M	Nitrogen, Ammonia	22	0	1.21	0.24	NA	NA	2.31	2.5	Y(B)	mg/l
GW-62M	Sodium, Dissolved	20	0	30.27	4.48	NA	NA	50.45	52.8	Y(B)	mg/l
GW-62M	Specific Conductance	21	0	370.28	105.52	NA	NA	845.10	591	N	umhos/cm
GW-62M	Sulfate as SO4	21	0	43.01	12.59	NA	NA	99.66	66.6	N	mg/l
GW-62S	Chloride	24	0	49.19	9.20	NA	NA	90.58	73	N	mg/l
GW-62S	Nitrogen, Ammonia	24	0	1.48	0.60	NA	NA	4.18	4	N	mg/l
GW-62S	Sodium, Dissolved	22	0	29.14	3.16	NA	NA	43.35	38	Y(C)	mg/l
GW-62S	Specific Conductance	23	0	383.81	85.95	NA	NA	770.57	486	N	umhos/cm
GW-62S	Sulfate as SO4	23	0	NA	NA	3.70	0.19	96.02	65	N	mg/l
GW-63D	Chloride	29	0	NA	NA	4.41	0.28	286.38	188	N	mg/l
GW-63D	Nitrogen, Ammonia	27	0	NA	NA	-0.21	1.41	455.10	14000	N	ug/l
GW-63D	Sodium, Dissolved	27	0	44.76	18.25	NA	NA	126.88	142	N	mg/l
GW-63D	Specific Conductance	29	0	562.20	330.77	NA	NA	2050.65	1640	N	umhos/cm
GW-63D	Sulfate as SO4	29	0	NA	NA	4.21	0.93	4428.31	454	N	mg/l
GW-63S	Chloride	26	0	NA	NA	4.50	0.36	448.55	240	N	mg/l
GW-63S	Nitrogen, Ammonia	27	22	NA	NA	-0.95	1.20	87.59	3725	N	ug/l
GW-63S	Sodium, Dissolved	27	0	NA	NA	3.77	0.35	210.15	120	N	mg/l
GW-63S	Specific Conductance	28	0	NA	NA	5.82	0.48	2860.48	1320	N	mg/l
GW-63S	Sulfate as SO4	25	0	NA	NA	3.01	0.88	1081.47	190.5	N	mg/l
GW-64D	Chloride	31	0	156.79	54.20	NA	NA	400.67	298	N	mg/l
GW-64D	Nitrogen, Ammonia	29	0	NA	NA	2.49	0.54	136.00	28	N	mg/l
GW-64D	Sodium, Dissolved	29	0	NA	NA	4.76	0.43	811.74	236.67	N	mg/l
GW-64D	Specific Conductance	31	0	1165.03	443.13	NA	NA	3159.11	2253.33	N	umhos/cm
GW-64D	Sulfate as SO4	31	0	NA	NA	5.58	0.57	3411.86	760.33	N	mg/l
GW-65D	Chloride	21	0	58.52	6.51	NA	NA	87.81	78.3	Y(B)	mg/l
GW-65D	Nitrogen, Ammonia	18	6	0.68	0.14	NA	NA	1.29	0.93	N	mg/l
GW-65D	Sodium, Dissolved	19	0	32.71	4.96	NA	NA	55.03	41.4	Y(B)	mg/l
GW-65D	Specific Conductance	21	0	400.31	73.72	NA	NA	732.03	560	N	umhos/cm
GW-65D	Sulfate as SO4	21	0	69.94	22.32	NA	NA	170.38	109	N	mg/l

Table 2 (cont.). Results of the Shewhart/CUSUM Control Chart Tests

		Background Statistics									
				Normal		Lognormal		Shewhart			
Location	Parameter	N	%BDL	Mean	SD	Mean	SD	UPCL[1]	Max	Exceedance	Units
GW-65S	Chloride	18	0	68.47	11.81	NA	NA	121.61	120	Y(B)	mg/l
GW-65S	Nitrogen, Ammonia	18	0	1.96	0.83	NA	NA	5.72	3.5	N	mg/l
GW-65S	Sodium, Dissolved	18	0	40.74	8.77	NA	NA	80.19	75	Y(B)	mg/l
GW-65S	Specific Conductance	18	0	370.67	113.49	NA	NA	881.37	602	Y(C)	umhos/cm
GW-65S	Sulfate as SO4	18	6	51.49	42.16	NA	NA	241.21	156	N	mg/l
GW-73D	Chloride	27	0	74.64	21.72	NA	NA	172.36	140	N	mg/l
GW-73D	Nitrogen, Ammonia	27	37	0.05	0.07	NA	NA	0.37	0.5	N	mg/l
GW-73D	Sodium, Dissolved	26	0	24.71	5.71	NA	NA	50.40	39	N	mg/l
GW-73D	Specific Conductance	27	0	402.97	73.73	NA	NA	734.75	604	N	umhos/cm
GW-73D	Sulfate as SO4	27	0	26.33	4.14	NA	NA	44.94	38	Y(B)	mg/l
GW-83D	Chloride	10	0	5663.50	1553.44	NA	NA	12653.98	8880	N	mg/l
GW-83D	Nitrogen, Ammonia	10	0	1044.10	479.16	NA	NA	3200.31	1650	N	mg/l
GW-83D	Sodium, Dissolved	10	0	4898.11	1747.61	NA	NA	12762.34	6120	N	mg/l
GW-83D	Specific Conductance	12	0	85870.83	115060.39	NA	NA	603642.60	335000	N	umhos/cm
GW-83D	Sulfate as SO4	10	0	17160.00	5839.96	NA	NA	43439.82	24000	N	mg/l
GW-83M	Chloride	12	0	113.46	18.86	NA	NA	198.33	141	Y(C)	mg/l
GW-83M	Nitrogen, Ammonia	12	0	24.47	6.85	NA	NA	55.31	31	Y(B)	mg/l
GW-83M	Sodium, Dissolved	13	0	60.29	9.34	NA	NA	102.31	100	Y(B)	mg/l
GW-83M	Specific Conductance	13	0	810.77	141.46	NA	NA	1447.32	1040	N	umhos/cm
GW-83M	Sulfate as SO4	12	0	144.21	46.70	NA	NA	354.34	229	Y(C)	mg/l
GW-83S	Chloride	10	0	90.06	11.37	NA	NA	141.25	103	Y(C)	mg/l
GW-83S	Nitrogen, Ammonia	11	0	NA	NA	1.05	0.35	13.78	7.7	N	mg/l
GW-83S	Sodium, Dissolved	11	0	49.14	6.53	NA	NA	78.54	69.9	Y(C)	mg/l
GW-83S	Specific Conductance	11	0	495.20	41.18	NA	NA	680.50	614	N	umhos/cm
GW-83S	Sulfate as SO4	10	0	86.71	21.73	NA	NA	184.50	144	N	mg/l
GW-84D	Chloride	18	0	894.20	508.62	NA	NA	3183.00	1800	N	mg/l
GW-84D	Nitrogen, Ammonia	17	0	108.55	84.95	NA	NA	490.82	360	Y(C)	mg/l
GW-84D	Sodium, Dissolved	16	0	956.64	447.93	NA	NA	2972.34	1440	N	mg/l
GW-84D	Specific Conductance	18	0	7001.42	3540.55	NA	NA	22933.88	12000	Y(C)	umhos/cm
GW-84D	Sulfate as SO4	18	0	3039.15	1270.11	NA	NA	8754.64	4590	N	mg/l
GW-84M	Chloride	17	0	141.29	19.21	NA	NA	227.73	160	N	mg/l
GW-84M	Nitrogen, Ammonia	17	24	0.39	0.39	NA	NA	2.14	1.02	Y(B)	mg/l
GW-84M	Sodium, Dissolved	16	0	57.32	7.71	NA	NA	92.02	79	N	mg/l
GW-84M	Specific Conductance	18	0	633.87	71.91	NA	NA	957.44	708	N	umhos/cm
GW-84M	Sulfate as SO4	17	0	30.38	4.75	NA	NA	51.76	40.3	N	mg/l

Table 2 (cont.). Results of the Shewhart/CUSUM Control Chart Tests

		Background Statistics									
				Normal		Lognormal		Shewhart			
Location	Parameter	N	%BDL	Mean	SD	Mean	SD	UPCL[1]	Max	Exceedance	Units
GW-85D	Chloride	18	0	530.92	220.77	NA	NA	1524.39	1063.67	N	mg/l
GW-85D	Nitrogen, Ammonia	18	0	79.71	33.52	NA	NA	230.54	116	Y(C)	mg/l
GW-85D	Sodium, Dissolved	17	0	429.46	113.76	NA	NA	941.39	557	N	mg/l
GW-85D	Specific Conductance	18	0	4404.15	893.42	NA	NA	8424.54	6420	Y(C)	umhos/cm
GW-85D	Sulfate as SO4	18	0	1530.57	377.80	NA	NA	3230.64	2226.67	N	mg/l
GW-85M	Chloride	17	0	217.61	140.55	NA	NA	850.08	710	N	mg/l
GW-85M	Nitrogen, Ammonia	18	0	13.27	10.93	NA	NA	62.45	46	N	mg/l
GW-85M	Sodium, Dissolved	17	0	NA	NA	4.79	0.57	1524.44	420	N	mg/l
GW-85M	Specific Conductance	18	0	1416.94	732.43	NA	NA	4712.87	3800	N	umhos/cm
GW-85M	Sulfate as SO4	17	0	377.07	395.30	NA	NA	2155.90	1800	N	mg/l
GW-86D	Chloride	24	0	379.48	135.61	NA	NA	989.74	670	N	mg/l
GW-86D	Nitrogen, Ammonia	25	0	50.75	18.49	NA	NA	133.93	74	N	mg/l
GW-86D	Sodium, Dissolved	25	0	307.10	76.20	NA	NA	649.99	420	N	mg/l
GW-86D	Specific Conductance	24	0	2988.15	746.96	NA	NA	6349.45	4070	Y(B)	umhos/cm
GW-86D	Sulfate as SO4	24	0	918.57	314.18	NA	NA	2332.36	1390	N	mg/l
GW-86M	Chloride	24	0	83.52	29.96	NA	NA	218.35	189.7	N	mg/l
GW-86M	Nitrogen, Ammonia	23	0	11.86	46.29	NA	NA	220.14	223.4	N	mg/l
GW-86M	Sodium, Dissolved	23	0	42.51	11.48	NA	NA	94.16	74.45	N	mg/l
GW-86M	Specific Conductance	23	0	475.97	96.11	NA	NA	908.48	799.33	N	umhos/cm
GW-86M	Sulfate as SO4	24	0	NA	NA	4.14	0.31	253.87	147	N	mg/l
GW-86S	Chloride	16	0	73.91	71.23	NA	NA	394.47	415	N	mg/l
GW-86S	Nitrogen, Ammonia	15	0	5.18	9.82	NA	NA	49.36	40.6	N	mg/l
GW-86S	Sodium, Dissolved	15	0	55.97	65.69	NA	NA	351.56	319	N	mg/l
GW-86S	Specific Conductance	16	0	725.41	568.88	NA	NA	3285.35	2840	N	umhos/cm
GW-86S	Sulfate as SO4	16	0	108.80	207.91	NA	NA	1044.39	873	N	mg/l
GW-87D	Chloride	16	0	345.60	194.56	NA	NA	1221.10	940	N	mg/l
GW-87D	Nitrogen, Ammonia	17	0	42.18	10.08	NA	NA	87.52	56	N	mg/l
GW-87D	Sodium, Dissolved	17	0	322.87	65.78	NA	NA	618.87	559	N	mg/l
GW-87D	Specific Conductance	17	0	3527.35	684.79	NA	NA	6608.90	5080	Y(B)	umhos/cm
GW-87D	Sulfate as SO4	16	0	857.37	358.69	NA	NA	2471.47	1680	N	mg/l
GW-103D	Chloride	16	0	NA	NA	3.83	0.19	110.57	109.5	N	mg/l
GW-103D	Nitrogen, Ammonia	17	65	NA	NA	NA	NA	NA	2	N	mg/l
GW-103D	Sodium, Dissolved	16	0	NA	NA	3.22	0.16	50.75	48.65	Y(B)	mg/l
GW-103D	Specific Conductance	17	0	336.74	96.33	NA	NA	770.22	692	N	umhos/cm
GW-103D	Sulfate as SO4	16	0	46.51	32.91	NA	NA	194.59	137	N	mg/l

Y(C) = CUSUM-only exceedance

Y(B) = Both Shewhart and CUSUM exceedance

Note: All units expressed in mg/L except for specific conductance (umhos/cm).

[1]The Shewhart Limits = Mean + 4.5x(St. Dev.) For the logrithmic data, limits have been converted back to concentration units to aid comparisons to raw data. Limits for the CUSUM criteria are not listed as the test is not performed on raw data, but on a value calculated from raw data (cumulative sum in St. Dev. units) that is dependent upon previous data.

Table 3. Results of the Kendall Test for Trend

Location	Parameter	N	Max	Z	p	Trend
GW-62D	Chloride	27	110	1.251	0.211	N
GW-62D	Nitrogen, Ammonia	27	14.75	2.419	0.016	Y+
GW-62D	Sodium, Dissolved	25	72	1.706	0.088	Y+
GW-62D	Specific Conductance	26	642	1.367	0.172	N
GW-62D	Sulfate as SO4	27	120.33	-0.938	0.348	N
GW-62M	Chloride	24	105	4.268	0.000	Y+
GW-62M	Nitrogen, Ammonia	25	2.9	4.537	0.000	Y+
GW-62M	Sodium, Dissolved	23	60	4.387	0.000	Y+
GW-62M	Specific Conductance	24	597	2.630	0.009	Y+
GW-62M	Sulfate as SO4	24	76	1.241	0.215	N
GW-62S	Chloride	27	73	0.917	0.359	N
GW-62S	Nitrogen, Ammonia	27	4	2.733	0.006	Y+
GW-62S	Sodium, Dissolved	25	43	1.614	0.107	N
GW-62S	Specific Conductance	26	486	-1.367	0.172	N
GW-62S	Sulfate as SO4	26	65	-3.661	0.000	Y-
GW-63D	Chloride	35	188	2.588	0.010	Y+
GW-63D	Nitrogen, Ammonia	33	14	4.355	0.000	Y+
GW-63D	Sodium, Dissolved	33	142	3.766	0.000	Y+
GW-63D	Specific Conductance	35	1640	2.202	0.028	Y+
GW-63D	Sulfate as SO4	35	454	1.818	0.069	Y+
GW-63S	Chloride	33	240	0.372	0.710	N
GW-63S	Nitrogen, Ammonia	34	3.725	0.000	1.000	N
GW-63S	Sodium, Dissolved	34	120	2.892	0.004	Y+
GW-63S	Specific Conductance	34	1320	2.120	0.034	Y+
GW-63S	Sulfate as SO4	32	190.5	1.719	0.086	Y+
GW-64D	Chloride	38	298	-2.038	0.042	Y-
GW-64D	Nitrogen, Ammonia	36	28	-1.321	0.186	N
GW-64D	Sodium, Dissolved	36	236.67	-2.030	0.042	Y-
GW-64D	Specific Conductance	38	2253.33	-2.401	0.016	Y-
GW-64D	Sulfate as SO4	38	760.33	-3.194	0.001	Y-
GW-65D	Chloride	27	120	4.257	0.000	Y+
GW-65D	Nitrogen, Ammonia	24	0.93	2.510	0.012	Y+
GW-65D	Sodium, Dissolved	25	66	3.112	0.002	Y+
GW-65D	Specific Conductance	27	572	3.315	0.001	Y+
GW-65D	Sulfate as SO4	27	109	-1.773	0.076	Y-
GW-65S	Chloride	24	160	3.920	0.000	Y+
GW-65S	Nitrogen, Ammonia	24	3.5	0.199	0.843	N
GW-65S	Sodium, Dissolved	24	100	4.397	0.000	Y+
GW-65S	Specific Conductance	24	790	4.688	0.000	Y+
GW-65S	Sulfate as SO4	24	156	-0.422	0.673	N
GW-73D	Chloride	33	140	-3.165	0.002	Y-
GW-73D	Nitrogen, Ammonia	33	0.5	1.230	0.219	N
GW-73D	Sodium, Dissolved	32	39	-2.411	0.016	Y-
GW-73D	Specific Conductance	33	604	-2.557	0.011	Y-
GW-73D	Sulfate as SO4	33	61	3.582	0.000	Y+
GW-83D	Chloride	15	8880	0.297	0.767	N
GW-83D	Nitrogen, Ammonia	15	2800	0.396	0.692	N
GW-83D	Sodium, Dissolved	14	6120	-0.274	0.784	N
GW-83D	Specific Conductance	16	335000	1.756	0.079	Y+
GW-83D	Sulfate as SO4	15	24000	1.043	0.297	N

Table 3 (cont.). Results of the Kendall Test for Trend

Location	Parameter	N	Max	Z	p	Trend
GW-83M	Chloride	17	180	3.469	0.001	Y+
GW-83M	Nitrogen, Ammonia	17	66	1.246	0.213	N
GW-83M	Sodium, Dissolved	17	120	4.205	0.000	Y+
GW-83M	Specific Conductance	17	1100	1.732	0.083	Y+
GW-83M	Sulfate as SO4	17	260	1.857	0.063	Y+
GW-83S	Chloride	15	120	2.078	0.038	Y+
GW-83S	Nitrogen, Ammonia	16	7.7	2.434	0.015	Y+
GW-83S	Sodium, Dissolved	15	74	3.563	0.000	Y+
GW-83S	Specific Conductance	15	621	2.626	0.009	Y+
GW-83S	Sulfate as SO4	15	144	0.248	0.804	N
GW-84D	Chloride	23	1800	-0.502	0.615	N
GW-84D	Nitrogen, Ammonia	22	370	2.425	0.015	Y+
GW-84D	Sodium, Dissolved	20	1440	1.010	0.312	N
GW-84D	Specific Conductance	22	16000	2.087	0.037	Y+
GW-84D	Sulfate as SO4	23	4590	0.608	0.543	N
GW-84M	Chloride	22	160	-0.768	0.443	N
GW-84M	Nitrogen, Ammonia	22	3.9	1.074	0.283	N
GW-84M	Sodium, Dissolved	20	81	2.693	0.007	Y+
GW-84M	Specific Conductance	22	708	-3.560	0.000	Y-
GW-84M	Sulfate as SO4	22	40.3	-0.650	0.516	N
GW-85D	Chloride	22	1063.67	-0.338	0.735	N
GW-85D	Nitrogen, Ammonia	22	200	0.961	0.337	N
GW-85D	Sodium, Dissolved	21	557	0.453	0.650	N
GW-85D	Specific Conductance	21	7670	-0.332	0.740	N
GW-85D	Sulfate as SO4	22	2226.67	-0.592	0.554	N
GW-85M	Chloride	21	710	-0.030	0.976	N
GW-85M	Nitrogen, Ammonia	22	46	-1.269	0.204	N
GW-85M	Sodium, Dissolved	21	420	0.302	0.763	N
GW-85M	Specific Conductance	21	3800	-1.298	0.194	N
GW-85M	Sulfate as SO4	21	1800	-1.390	0.165	N
GW-86D	Chloride	30	670	-1.482	0.138	N
GW-86D	Nitrogen, Ammonia	31	110	1.156	0.248	N
GW-86D	Sodium, Dissolved	31	420	-1.006	0.314	N
GW-86D	Specific Conductance	29	6500	0.075	0.940	N
GW-86D	Sulfate as SO4	30	1390	-0.928	0.353	N
GW-86M	Chloride	30	189.7	0.963	0.335	N
GW-86M	Nitrogen, Ammonia	30	223.4	-4.089	0.000	Y-
GW-86M	Sodium, Dissolved	29	74.45	1.316	0.188	N
GW-86M	Specific Conductance	29	799.33	-0.507	0.612	N
GW-86M	Sulfate as SO4	30	147	-1.982	0.048	Y-
GW-86S	Chloride	22	415	4.372	0.000	Y+
GW-86S	Nitrogen, Ammonia	21	40.6	1.422	0.155	N
GW-86S	Sodium, Dissolved	21	319	4.275	0.000	Y+
GW-86S	Specific Conductance	22	2840	2.793	0.005	Y+
GW-86S	Sulfate as SO4	22	873	-4.598	0.000	Y-
GW-87D	Chloride	22	940	1.777	0.076	Y+
GW-87D	Nitrogen, Ammonia	23	80.2	-0.793	0.428	N
GW-87D	Sodium, Dissolved	23	559	2.169	0.030	Y+
GW-87D	Specific Conductance	23	8610	3.859	0.000	Y+
GW-87D	Sulfate as SO4	22	1800	3.529	0.000	Y+

Table 3 (cont.). Results of the Kendall Test for Trend

Location	Parameter	N	Max	Z	p	Trend
GW-103D	Chloride	22	109.5	3.190	0.001	Y+
GW-103D	Nitrogen, Ammonia	25	2	1.188	0.235	N
GW-103D	Sodium, Dissolved	22	61.5	4.351	0.000	Y+
GW-103D	Specific Conductance	23	692	2.430	0.015	Y+
GW-103D	Sulfate as SO4	22	137	2.059	0.039	Y+

Y+ = Significant positive trend
Y- = Significant negative trend
N = No Significant trend

Table 4. Results of Kendall Tests for Trend, Comparisons with Previous Trend Test Results, and Comparisons with Control Chart Results

Location	Parameter	N	Max	Z	p	Trend	Change	Comment	Exceedance	Units
GW-62D	Chloride	27	110	1.251	0.211	N			Y(C)	mg/l
GW-62D	Nitrogen, Ammonia	27	14.75	2.419	0.016	Y+	X	Nonsignificant to significant	N	mg/l
GW-62D	Sodium, Dissolved	25	72	1.706	0.088	Y+	X	Nonsignificant to significant	Y(C)	mg/l
GW-62D	Specific Conductance	26	642	1.367	0.172	N			N	umhos/cm
GW-62D	Sulfate as SO4	27	120.33	-0.938	0.348	N			N	mg/l
GW-62M	Chloride	24	105	4.268	0.000	Y+			Y(C)	mg/l
GW-62M	Nitrogen, Ammonia	25	2.9	4.537	0.000	Y+			Y(B)	mg/l
GW-62M	Sodium, Dissolved	23	60	4.387	0.000	Y+			Y(B)	mg/l
GW-62M	Specific Conductance	24	597	2.630	0.009	Y+	X	Nonsignificant to significant	N	umhos/cm
GW-62M	Sulfate as SO4	24	76	1.241	0.215	N			N	mg/l
GW-62S	Chloride	27	73	0.917	0.359	N			N	mg/l
GW-62S	Nitrogen, Ammonia	27	4	2.733	0.006	Y+			N	mg/l
GW-62S	Sodium, Dissolved	25	43	1.614	0.107	N			Y(C)	mg/l
GW-62S	Specific Conductance	26	486	-1.367	0.172	N			N	umhos/cm
GW-62S	Sulfate as SO4	26	65	-3.661	0.000	Y-			N	mg/l
GW-63D	Chloride	35	188	2.588	0.010	Y+			N	mg/l
GW-63D	Nitrogen, Ammonia	33	14	4.355	0.000	Y+			N	ug/l
GW-63D	Sodium, Dissolved	33	142	3.766	0.000	Y+			N	mg/l
GW-63D	Specific Conductance	35	1640	2.202	0.028	Y+			N	umhos/cm
GW-63D	Sulfate as SO4	35	454	1.818	0.069	Y+	X	Nonsignificant to significant	N	mg/l
GW-63S	Chloride	33	240	0.372	0.710	N	X	Significant to nonsignificant	N	mg/l
GW-63S	Nitrogen, Ammonia	34	3.725	0.000	1.000	N			N	ug/l
GW-63S	Sodium, Dissolved	34	120	2.892	0.004	Y+			N	mg/l
GW-63S	Specific Conductance	34	1320	2.120	0.034	Y+			N	mg/l
GW-63S	Sulfate as SO4	32	190.5	1.719	0.086	Y+	X	Nonsignificant to significant	N	mg/l
GW-64D	Chloride	38	298	-2.038	0.042	Y-	X	Nonsignificant to significant	N	mg/l
GW-64D	Nitrogen, Ammonia	36	28	-1.321	0.186	N			N	mg/l
GW-64D	Sodium, Dissolved	36	236.67	-2.030	0.042	Y-	X	Nonsignificant to significant	N	mg/l
GW-64D	Specific Conductance	38	2253.33	-2.401	0.016	Y-	X	Nonsignificant to significant	N	umhos/cm
GW-64D	Sulfate as SO4	38	760.33	-3.194	0.001	Y-	X	Nonsignificant to significant	N	mg/l
GW-65D	Chloride	27	120	4.257	0.000	Y+			Y(B)	mg/l
GW-65D	Nitrogen, Ammonia	24	0.93	2.510	0.012	Y+			N	mg/l
GW-65D	Sodium, Dissolved	25	66	3.112	0.002	Y+	X	Nonsignificant to significant	Y(B)	mg/l
GW-65D	Specific Conductance	27	572	3.315	0.001	Y+			N	umhos/cm
GW-65D	Sulfate as SO4	27	109	-1.773	0.076	Y-	X	Nonsignificant to significant	N	mg/l
GW-65S	Chloride	24	160	3.920	0.000	Y+			Y(B)	mg/l
GW-65S	Nitrogen, Ammonia	24	3.5	0.199	0.843	N			N	mg/l
GW-65S	Sodium, Dissolved	24	100	4.397	0.000	Y+			Y(B)	mg/l
GW-65S	Specific Conductance	24	790	4.688	0.000	Y+			Y(C)	umhos/cm
GW-65S	Sulfate as SO4	24	156	-0.422	0.673	N			N	mg/l

Table 4 (cont.). Results of Kendall Tests for Trend, Comparisons with Previous Trend Test Results, and Comparisons with Control Chart Results

Location	Parameter	N	Max	Z	p	Trend	Change	Comment	Exceedance	Units
GW-73D	Chloride	33	140	-3.165	0.002	Y-			N	mg/l
GW-73D	Nitrogen, Ammonia	33	0.5	1.230	0.219	N			N	mg/l
GW-73D	Sodium, Dissolved	32	39	-2.411	0.016	Y-			N	mg/l
GW-73D	Specific Conductance	33	604	-2.557	0.011	Y-			N	umhos/cm
GW-73D	Sulfate as SO4	33	61	3.582	0.000	Y+			Y(B)	mg/l
GW-83D	Chloride	15	8880	0.297	0.767	N			N	mg/l
GW-83D	Nitrogen, Ammonia	15	2800	0.396	0.692	N			N	mg/l
GW-83D	Sodium, Dissolved	14	6120	-0.274	0.784	N			N	mg/l
GW-83D	Specific Conductance	16	335000	1.756	0.079	Y+	X	Nonsignificant to significant	N	umhos/cm
GW-83D	Sulfate as SO4	15	24000	1.043	0.297	N			N	mg/l
GW-83M	Chloride	17	180	3.469	0.001	Y+			Y(C)	mg/l
GW-83M	Nitrogen, Ammonia	17	66	1.246	0.213	N			Y(B)	mg/l
GW-83M	Sodium, Dissolved	17	120	4.205	0.000	Y+			Y(B)	mg/l
GW-83M	Specific Conductance	17	1100	1.732	0.083	Y+	X	Nonsignificant to significant	N	umhos/cm
GW-83M	Sulfate as SO4	17	260	1.857	0.063	Y+	X	Nonsignificant to significant	Y(C)	mg/l
GW-83S	Chloride	15	120	2.078	0.038	Y+			Y(C)	mg/l
GW-83S	Nitrogen, Ammonia	16	7.7	2.434	0.015	Y+			N	mg/l
GW-83S	Sodium, Dissolved	15	74	3.563	0.000	Y+			Y(C)	mg/l
GW-83S	Specific Conductance	15	621	2.626	0.009	Y+	X	Nonsignificant to significant	N	umhos/cm
GW-83S	Sulfate as SO4	15	144	0.248	0.804	N			N	mg/l
GW-84D	Chloride	23	1800	-0.502	0.615	N			N	mg/l
GW-84D	Nitrogen, Ammonia	22	370	2.425	0.015	Y+	X	Nonsignificant to significant	Y(C)	mg/l
GW-84D	Sodium, Dissolved	20	1440	1.010	0.312	N			N	mg/l
GW-84D	Specific Conductance	22	16000	2.087	0.037	Y+	X	Nonsignificant to significant	Y(C)	umhos/cm
GW-84D	Sulfate as SO4	23	4590	0.608	0.543	N			N	mg/l
GW-84M	Chloride	22	160	-0.768	0.443	N			N	mg/l
GW-84M	Nitrogen, Ammonia	22	3.9	1.074	0.283	N			Y(B)	mg/l
GW-84M	Sodium, Dissolved	20	81	2.693	0.007	Y+			N	mg/l
GW-84M	Specific Conductance	22	708	-3.560	0.000	Y-			N	umhos/cm
GW-84M	Sulfate as SO4	22	40.3	-0.650	0.516	N			N	mg/l
GW-85D	Chloride	22	1063.67	-0.338	0.735	N			N	mg/l
GW-85D	Nitrogen, Ammonia	22	200	0.961	0.337	N			Y(C)	mg/l
GW-85D	Sodium, Dissolved	21	557	0.453	0.650	N			N	mg/l
GW-85D	Specific Conductance	21	7670	-0.332	0.740	N	X	Significant negative to nonsignificant	Y(C)	umhos/cm
GW-85D	Sulfate as SO4	22	2226.67	-0.592	0.554	N	X	Significant negative to nonsignificant	N	mg/l
GW-85M	Chloride	21	710	-0.030	0.976	N			N	mg/l
GW-85M	Nitrogen, Ammonia	22	46	-1.269	0.204	N			N	mg/l
GW-85M	Sodium, Dissolved	21	420	0.302	0.763	N			N	mg/l
GW-85M	Specific Conductance	21	3800	-1.298	0.194	N			N	umhos/cm
GW-85M	Sulfate as SO4	21	1800	-1.390	0.165	N			N	mg/l

Table 4 (cont.). Results of Kendall Tests for Trend, Comparisons with Previous Trend Test Results, and Comparisons with Control Chart Results

Location	Parameter	N	Max	Z	p	Trend	Change	Comment	Exceedance	Units
GW-86D	Chloride	30	670	-1.482	0.138	N			N	mg/l
GW-86D	Nitrogen, Ammonia	31	110	1.156	0.248	N			N	mg/l
GW-86D	Sodium, Dissolved	31	420	-1.006	0.314	N			N	mg/l
GW-86D	Specific Conductance	29	6500	0.075	0.940	N	X	Significant negative to nonsignificant	Y(B)	umhos/cm
GW-86D	Sulfate as SO4	30	1390	-0.928	0.353	N	X	Significant negative to nonsignificant	N	mg/l
GW-86M	Chloride	30	189.7	0.963	0.335	N			N	mg/l
GW-86M	Nitrogen, Ammonia	30	223.4	-4.089	0.000	Y-			N	mg/l
GW-86M	Sodium, Dissolved	29	74.45	1.316	0.188	N			N	mg/l
GW-86M	Specific Conductance	29	799.33	-0.507	0.612	N			N	umhos/cm
GW-86M	Sulfate as SO4	30	147	-1.982	0.048	Y-	X	Nonsignificant to significant	N	mg/l
GW-86S	Chloride	22	415	4.372	0.000	Y+			N	mg/l
GW-86S	Nitrogen, Ammonia	21	40.6	1.422	0.155	N			N	mg/l
GW-86S	Sodium, Dissolved	21	319	4.275	0.000	Y+			N	mg/l
GW-86S	Specific Conductance	22	2840	2.793	0.005	Y+	X	Nonsignificant to significant	N	umhos/cm
GW-86S	Sulfate as SO4	22	873	-4.598	0.000	Y-			N	mg/l
GW-87D	Chloride	22	940	1.777	0.076	Y+			N	mg/l
GW-87D	Nitrogen, Ammonia	23	80.2	-0.793	0.428	N			N	mg/l
GW-87D	Sodium, Dissolved	23	559	2.169	0.030	Y+			N	mg/l
GW-87D	Specific Conductance	23	8610	3.859	0.000	Y+			Y(B)	umhos/cm
GW-87D	Sulfate as SO4	22	1800	3.529	0.000	Y+	X	Nonsignificant to significant	N	mg/l
GW-103D	Chloride	22	109.5	3.190	0.001	Y+			N	mg/l
GW-103D	Nitrogen, Ammonia	25	2	1.188	0.235	N			N	mg/l
GW-103D	Sodium, Dissolved	22	61.5	4.351	0.000	Y+			Y(B)	mg/l
GW-103D	Specific Conductance	23	692	2.430	0.015	Y+			N	umhos/cm
GW-103D	Sulfate as SO4	22	137	2.059	0.039	Y+			N	mg/l

Y+ = Significant positive trend
Y- = Significant negative trend

Y(C) = CUSUM-only exceedance
Y(B) = Both Shewhart and CUSUM exceedance

N = No trend or No exceedance

Table 5. Results of Kendall Test for Trend in Bedrock Wells

Location	Parameter	N	Max	Z	p	Trend
GW-103BR	Chloride	22	131	-3.838	0.000	Y-
GW-103BR	Nitrogen, Ammonia	22	16.4	-3.102	0.002	Y-
GW-103BR	Sodium, Dissolved	22	82.5	-2.795	0.005	Y-
GW-103BR	Specific Conductance	22	1098	-3.440	0.001	Y-
GW-103BR	Sulfate as SO4	22	290	-3.188	0.001	Y-
GW-62BR	Chloride	11	2150	0.079	0.937	N
GW-62BR	Nitrogen, Ammonia	11	190	2.733	0.006	Y+
GW-62BR	Sodium, Dissolved	12	2300	0.069	0.945	N
GW-62BR	Specific Conductance	11	19100	0.934	0.350	N
GW-62BR	Sulfate as SO4	11	4900	-0.156	0.876	N
GW-65BR	Chloride	9	64	0.000	1.000	N
GW-65BR	Nitrogen, Ammonia	10	1.65	1.623	0.105	N
GW-65BR	Sodium, Dissolved	10	130	1.789	0.074	Y+
GW-65BR	Specific Conductance	9	3790	1.564	0.118	N
GW-65BR	Sulfate as SO4	9	200	-2.846	0.004	Y-

Y+ = Significant positive trend

Y- = Significant negative trend

N = No significant trend

Table 6. Results of the Kendall Tests for Trend for the Sanmina Wells

Location	Parameter	N	Max	Z	p	Trend
ALTRON B1	Chloride	82	180	4.840	0.000	Y+
ALTRON B1	Nitrogen, Ammonia	85	62	-6.240	0.000	Y-
ALTRON B1	Sodium, Dissolved	16	100	-0.225	0.822	N
ALTRON B1	Specific Conductance	68	1200	1.212	0.225	N
ALTRON B1	Sulfate as SO4	85	316	-5.554	0.000	Y-
ALTRON B3	Chloride	77	300	5.330	0.000	Y+
ALTRON B3	Nitrogen, Ammonia	80	66	-0.220	0.826	N
ALTRON B3	Sodium, Dissolved	16	140	2.858	0.004	Y+
ALTRON B3	Specific Conductance	65	1200	4.886	0.000	Y+
ALTRON B3	Sulfate as SO4	80	407	1.471	0.141	N

Y+ = Significant positive trend

Y- = Significant negative trend

N = No significant trend

Table 7. Statistical Summary of Surface Water Data in Maple Meadow Brook and Sawmill Brook.

Location	Parameter	Min Date	Max Date	N	N-BDL	%BDL	Min	Max	Mean	Median
MMB-SW/SD-1	Calcium, Dissolved	12/11/2000	11/18/2004	8	0	0	15	35.3	21.8	20.5
MMB-SW/SD-1	Chloride	12/11/2000	11/18/2004	9	0	0	85.6	268	132.29	110
MMB-SW/SD-1	Nitrogen, Ammonia	12/11/2000	11/18/2004	11	0	0	0.12	0.88	0.41	0.32
MMB-SW/SD-1	Sodium, Dissolved	12/11/2000	11/18/2004	11	0	0	41	150	68.07	55
MMB-SW/SD-1	Specific Conductance	12/11/2000	11/18/2004	9	0	0	371	890	503.33	421
MMB-SW/SD-1	Sulfate as SO4	12/11/2000	11/18/2004	11	0	0	6.2	18.2	10.91	11
MMB-SW/SD-10	Calcium, Dissolved	11/12/2003	11/17/2004	5	0	0	14	37.6	23.62	21
MMB-SW/SD-10	Chloride	11/12/2003	11/17/2004	5	0	0	76	245	151.78	150
MMB-SW/SD-10	Nitrogen, Ammonia	11/12/2003	11/17/2004	5	0	0	0.11	1	0.48	0.42
MMB-SW/SD-10	Sodium, Dissolved	11/12/2003	11/17/2004	5	0	0	45	131	81.66	81
MMB-SW/SD-10	Specific Conductance	11/12/2003	11/17/2004	5	0	0	309	832	555	532
MMB-SW/SD-10	Sulfate as SO4	11/12/2003	11/17/2004	5	0	0	8	16	11.96	11
MMB-SW/SD-11	Calcium, Dissolved	11/13/2003	11/15/2004	5	0	0	15	34	24.72	21.7
MMB-SW/SD-11	Chloride	11/13/2003	11/15/2004	5	0	0	86	740	244.8	130
MMB-SW/SD-11	Nitrogen, Ammonia	11/13/2003	11/15/2004	5	0	0	0.28	1.82	0.94	0.88
MMB-SW/SD-11	Sodium, Dissolved	11/13/2003	11/15/2004	5	0	0	49	350	147.06	83
MMB-SW/SD-11	Specific Conductance	11/13/2003	11/15/2004	5	0	0	337	2810	1049.2	543
MMB-SW/SD-11	Sulfate as SO4	11/13/2003	11/15/2004	5	0	0	7	18.7	14.2	15.3
MMB-SW/SD-2	Calcium, Dissolved	10/17/2001	11/16/2004	7	0	0	23	33	28.63	30
MMB-SW/SD-2	Chloride	11/10/2003	11/16/2004	5	0	0	86	111	98.28	98
MMB-SW/SD-2	Nitrogen, Ammonia	10/17/2001	11/16/2004	7	0	0	0.35	1.88	0.91	0.89
MMB-SW/SD-2	Sodium, Dissolved	10/17/2001	11/16/2004	7	0	0	39	70	50.83	50
MMB-SW/SD-2	Specific Conductance	11/10/2003	11/16/2004	5	0	0	367	582	460	439
MMB-SW/SD-2	Sulfate as SO4	10/17/2001	11/16/2004	7	0	0	8	22	15.96	16.9
MMB-SW/SD-3	Calcium, Dissolved	10/17/2001	11/16/2004	7	0	0	2.5	33.3	22.96	25.7
MMB-SW/SD-3	Chloride	11/11/2003	11/16/2004	5	0	0	49	150	101.58	88
MMB-SW/SD-3	Nitrogen, Ammonia	10/17/2001	11/16/2004	7	0	0	0.14	2.2	0.81	0.57
MMB-SW/SD-3	Sodium, Dissolved	10/17/2001	11/16/2004	7	0	0	29	68.1	48.84	44
MMB-SW/SD-3	Specific Conductance	11/11/2003	11/16/2004	5	0	0	207	531	417.8	439
MMB-SW/SD-3	Sulfate as SO4	10/17/2001	11/16/2004	7	1	14	<2	24	13.67	10.2
MMB-SW/SD-4	Calcium, Dissolved	10/18/2001	11/17/2004	8	0	0	15	33.4	25.05	25.75
MMB-SW/SD-4	Chloride	11/12/2003	11/17/2004	5	0	0	78	269	164.62	140
MMB-SW/SD-4	Nitrogen, Ammonia	10/18/2001	11/17/2004	8	0	0	0.16	1.9	0.84	0.705
MMB-SW/SD-4	Sodium, Dissolved	10/18/2001	11/17/2004	8	0	0	47	149	74.55	56.95
MMB-SW/SD-4	Specific Conductance	11/12/2003	11/17/2004	5	0	0	319	886	598.8	537
MMB-SW/SD-4	Sulfate as SO4	10/18/2001	11/17/2004	8	0	0	6	21	12.35	11.1
MMB-SW/SD-5	Calcium, Dissolved	10/18/2001	11/15/2004	7	0	0	15	35.8	24.14	21
MMB-SW/SD-5	Chloride	11/13/2003	11/15/2004	5	0	0	77	540	212.4	130
MMB-SW/SD-5	Nitrogen, Ammonia	10/18/2001	11/15/2004	7	0	0	0.18	1.42	0.52	0.35
MMB-SW/SD-5	Sodium, Dissolved	10/18/2001	11/15/2004	7	0	0	46	270	103.93	79.4

Table 7 (cont.). Statistical Summary of Surface Water Data in Maple Meadow Brook and Sawmill Brook.

Location	Parameter	Min Date	Max Date	N	N-BDL	%BDL	Min	Max	Mean	Median
MMB-SW/SD-5	Specific Conductance	11/13/2003	11/15/2004	5	0	0	314	1690	749.4	515
MMB-SW/SD-5	Sulfate as SO4	10/18/2001	11/15/2004	7	0	0	7.6	55	19.27	14.3
MMB-SW/SD-6	Calcium, Dissolved	10/17/2001	11/15/2004	6	0	0	23	44	30.85	29.5
MMB-SW/SD-6	Nitrogen, Ammonia	10/17/2001	11/15/2004	6	0	0	0.27	3.1	1.16	0.79
MMB-SW/SD-6	Sodium, Dissolved	10/17/2001	11/15/2004	6	0	0	34.5	50	41.75	41
MMB-SW/SD-6	Specific Conductance	11/10/2003	11/15/2004	4	0	0	320	524	424.5	427
MMB-SW/SD-6	Sulfate as SO4	10/17/2001	11/15/2004	6	1	17	<2	26	11.4	10.5
MMB-SW/SD-7	Calcium, Dissolved	10/17/2001	6/12/2002	2	0	0	20	25.5	22.75	22.75
MMB-SW/SD-7	Chloride	NA	NA	0	0	NA	NA	NA	NA	NA
MMB-SW/SD-7	Nitrogen, Ammonia	10/17/2001	6/12/2002	2	1	50	<0.1	0.1	0.08	0.1
MMB-SW/SD-7	Sodium, Dissolved	10/17/2001	6/12/2002	2	0	0	31	47.1	39.05	39.05
MMB-SW/SD-7	Specific Conductance	NA	NA	0	0	NA	NA	NA	NA	NA
MMB-SW/SD-7	Sulfate as SO4	10/17/2001	6/12/2002	2	0	0	13	14	13.5	13.5
MMB-SW/SD-8	Calcium, Dissolved	11/13/2003	11/18/2004	5	0	0	16	25.6	19.86	20
MMB-SW/SD-8	Chloride	11/13/2003	11/18/2004	5	0	0	110	238	144	122
MMB-SW/SD-8	Nitrogen, Ammonia	11/13/2003	11/18/2004	5	1	20	<0.1	0.7	0.45	0.5
MMB-SW/SD-8	Sodium, Dissolved	11/13/2003	11/18/2004	5	0	0	61.1	140	82.02	66
MMB-SW/SD-8	Specific Conductance	11/13/2003	11/18/2004	5	0	0	433	829	539	479
MMB-SW/SD-8	Sulfate as SO4	11/13/2003	11/18/2004	5	0	0	6.8	20.6	13.64	13
MMB-SW/SD-8A	Calcium, Dissolved	10/18/2001	11/15/2004	7	0	0	14	29	20.66	20
MMB-SW/SD-8A	Chloride	11/13/2003	11/15/2004	5	0	0	81	560	227	130
MMB-SW/SD-8A	Nitrogen, Ammonia	10/18/2001	11/15/2004	7	1	14	<0.1	0.65	0.29	0.24
MMB-SW/SD-8A	Sodium, Dissolved	10/18/2001	11/15/2004	7	0	0	47	270	108.5	79
MMB-SW/SD-8A	Specific Conductance	11/13/2003	11/15/2004	5	0	0	318	1740	780.8	517
MMB-SW/SD-8A	Sulfate as SO4	10/18/2001	11/15/2004	7	0	0	7.7	20.2	15.54	15
MMB-SW/SD-9	Calcium, Dissolved	11/13/2003	11/18/2004	5	0	0	19	36.7	23.66	20.6
MMB-SW/SD-9	Chloride	11/13/2003	11/18/2004	5	0	0	62	205	112.82	94
MMB-SW/SD-9	Nitrogen, Ammonia	11/13/2003	11/18/2004	5	0	0	0.3	1.24	0.57	0.37
MMB-SW/SD-9	Sodium, Dissolved	11/13/2003	11/18/2004	5	0	0	45.2	110	63.84	53
MMB-SW/SD-9	Specific Conductance	11/13/2003	11/18/2004	5	0	0	364	719	459.8	394
MMB-SW/SD-9	Sulfate as SO4	11/13/2003	11/18/2004	5	0	0	5.1	16.4	10.9	9.6

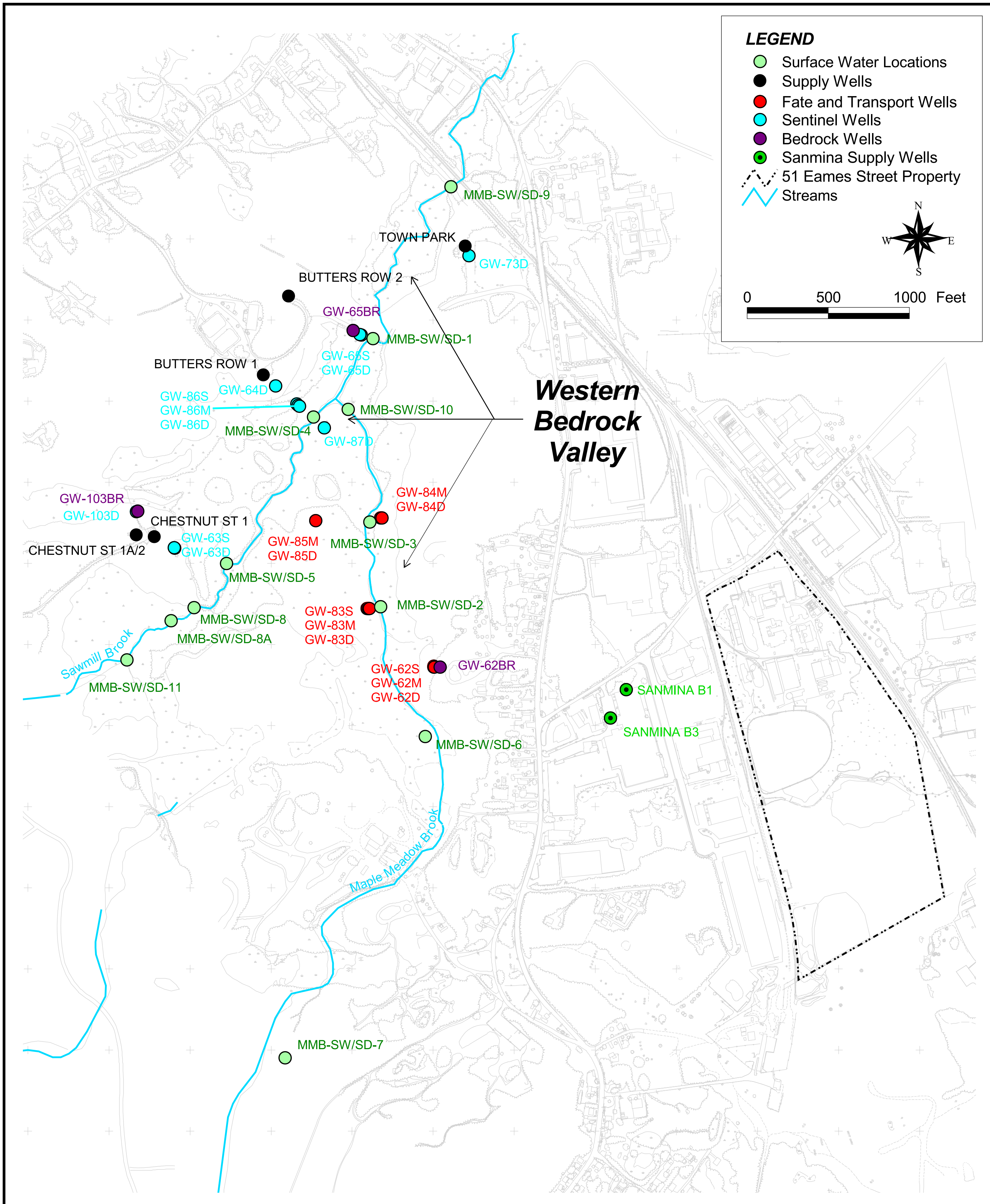
BDL = Below detection limit
NA = Not Applicable
Note: All units expressed in mg/L except for Specific Conductance (umhos/cm)
Calculations represent all historical data.

Table 8. Calculated Confidence Limits About the Mean and Median for Selected Parameters in Surface Water in Maple Meadow Brook and Sawmill Brook.

Sample Location	Parameter	Normal Distribution Assumption				Lognormal Distribution Assumption				Nonparametric			
		Mean	Std. Dev.	LCL	UCL	Mean	CV	LCL	UCL	Median	CI	LCL	UCL
MMB-SW/SD-1	Calcium, Dissolved	21.8	5.96	16.81	26.79	21.76	0.24	18.14	27.6	20.5	93	19	23
MMB-SW/SD-1	Chloride	132.29	57.5	88.09	176.49	131.27	0.36	103.08	186.07	110	89	99	160
MMB-SW/SD-1	Nitrogen, Ammonia	0.41	0.26	0.23	0.58	0.41	0.68	0.28	0.79	0.32	93	0.19	0.62
MMB-SW/SD-1	Sodium, Dissolved	68.07	30.7	47.45	88.7	67.47	0.37	54.29	91.01	55	93	50.2	84
MMB-SW/SD-1	Specific Conductance	503.33	169.68	372.91	633.76	501.45	0.29	410.41	656.74	421	89	386	604
MMB-SW/SD-1	Sulfate as SO4	10.91	4.04	8.2	13.62	10.91	0.38	8.74	14.83	11	93	6.7	13
MMB-SW/SD-10	Calcium, Dissolved	23.62	8.75	12.75	34.49	23.59	0.36	16.6	45.53	21	94	14	37.6
MMB-SW/SD-10	Chloride	151.78	68.56	66.66	236.9	152.11	0.47	97.57	424.48	150	94	76	245
MMB-SW/SD-10	Nitrogen, Ammonia	0.48	0.34	0.05	0.9	0.49	0.82	0.24	8	0.42	94	0.11	1
MMB-SW/SD-10	Sodium, Dissolved	81.66	35.15	38.02	125.3	81.71	0.44	53.8	202.77	81	94	45	131
MMB-SW/SD-10	Specific Conductance	555	205.58	299.74	810.26	555.78	0.39	382.05	1163.79	532	94	309	832
MMB-SW/SD-10	Sulfate as SO4	11.96	3.1	8.11	15.81	11.97	0.27	9.09	18.52	11	94	8	16
MMB-SW/SD-11	Calcium, Dissolved	24.72	7.99	14.8	34.64	24.74	0.33	17.74	44.99	21.7	94	15	34
MMB-SW/SD-11	Chloride	244.8	277.58	-99.86	589.46	224.54	0.82	111.98	3677.8	130	94	86	740
MMB-SW/SD-11	Nitrogen, Ammonia	0.94	0.67	0.1	1.78	0.96	0.83	0.47	16.84	0.88	94	0.28	1.82
MMB-SW/SD-11	Sodium, Dissolved	147.06	125.76	-9.09	303.21	143.92	0.79	73.11	1984.05	83	94	49	350
MMB-SW/SD-11	Specific Conductance	1049.2	1021.03	-218.58	2316.98	1004.25	0.81	502.72	15864.83	543	94	337	2810
MMB-SW/SD-11	Sulfate as SO4	14.2	4.38	8.77	19.63	14.3	0.38	9.88	29.48	15.3	94	7	18.7
MMB-SW/SD-2	Calcium, Dissolved	28.63	3.57	25.33	31.93	28.63	0.13	25.64	32.6	30	93	25.6	33
MMB-SW/SD-2	Nitrogen, Ammonia	0.91	0.53	0.42	1.4	0.92	0.6	0.59	2.28	0.89	93	0.43	1.88
MMB-SW/SD-2	Sodium, Dissolved	50.83	11.52	40.17	61.48	50.8	0.22	42.43	64.34	50	93	40.5	70
MMB-SW/SD-2	Specific Conductance	460	82	358.19	561.81	459.92	0.17	380.27	594.72	439	94	367	582
MMB-SW/SD-2	Sulfate as SO4	15.96	4.36	11.92	19.99	16.03	0.32	12.43	23.46	16.9	93	14	22
MMB-SW/SD-3	Calcium, Dissolved	22.96	10.81	12.96	32.95	25.91	0.93	13.78	172.27	25.7	93	15	33.3
MMB-SW/SD-3	Nitrogen, Ammonia	0.81	0.67	0.18	1.43	0.82	0.86	0.45	4.21	0.57	93	0.46	2.2
MMB-SW/SD-3	Sodium, Dissolved	48.84	14.76	35.19	62.5	48.86	0.31	38.27	69.92	44	93	40	68.1
MMB-SW/SD-3	Specific Conductance	417.8	127.7	259.24	576.36	420.85	0.38	291.12	861.64	439	94	207	531
MMB-SW/SD-3	Sulfate as SO4	13.26	8.37	6.71	19.81	15.77	1.12	3	28.54	10.2	93	10	24
MMB-SW/SD-4	Calcium, Dissolved	25.05	6.37	19.72	30.38	25.08	0.27	20.54	32.85	25.75	93	19.7	33
MMB-SW/SD-4	Nitrogen, Ammonia	0.84	0.62	0.32	1.36	0.86	0.87	0.5	3.45	0.7	93	0.26	1.59
MMB-SW/SD-4	Sodium, Dissolved	74.55	37.06	43.57	105.53	73.91	0.44	54.48	121.19	56.95	93	47.2	110
MMB-SW/SD-4	Specific Conductance	598.8	243.68	296.24	901.36	599.71	0.42	399.57	1416.83	537	94	319	886
MMB-SW/SD-4	Sulfate as SO4	12.35	5.79	7.51	17.19	12.38	0.5	8.8	22.39	11.1	93	6	18
MMB-SW/SD-5	Calcium, Dissolved	24.14	7.26	17.43	30.86	24.13	0.3	19.07	33.89	21	93	20.5	35.8
MMB-SW/SD-5	Nitrogen, Ammonia	0.52	0.43	0.12	0.91	0.5	0.7	0.31	1.61	0.35	93	0.24	1.42
MMB-SW/SD-5	Sodium, Dissolved	103.93	76.09	33.55	174.3	101.16	0.57	66.87	233.4	79.4	93	62.1	270
MMB-SW/SD-5	Specific Conductance	749.4	548.89	67.87	1430.93	734.84	0.63	420.76	3916.62	515	94	314	1690
MMB-SW/SD-5	Sulfate as SO4	19.27	15.99	4.49	34.06	18.54	0.6	11.98	46.54	14.3	93	13	55
MMB-SW/SD-6	Calcium, Dissolved	30.85	7.45	23.03	38.67	30.82	0.23	25.01	41.17	29.5	87	26.1	44
MMB-SW/SD-6	Chloride	73.05	26.62	30.69	115.41	73.28	0.4	46.31	241.28	75.6	88	41	100
MMB-SW/SD-6	Nitrogen, Ammonia	1.16	1.04	0.07	2.26	1.15	0.86	0.6	9.58	0.79	87	0.53	3.1
MMB-SW/SD-6	Sodium, Dissolved	41.75	5.14	36.36	47.14	41.75	0.12	37.07	48.09	41	87	40	50
MMB-SW/SD-6	Specific Conductance	424.5	83.66	291.38	557.62	424.63	0.2	325.35	650.86	427	88	320	524
MMB-SW/SD-6	Sulfate as SO4	10.84	8.42	3.42	18.27	12.91	1.13	1.43	24.38	10.5	87	8.4	26
MMB-SW/SD-8	Calcium, Dissolved	19.86	3.77	15.18	24.54	19.85	0.18	16.26	26.13	20	94	16	25.6
MMB-SW/SD-8	Nitrogen, Ammonia	0.43	0.28	0.16	0.69	0.51	1.1	0.02	1	0.5	94	0.1	0.7
MMB-SW/SD-8	Sodium, Dissolved	82.02	33.13	40.89	123.15	81.53	0.34	58.12	150.93	66	94	61.1	140
MMB-SW/SD-8	Specific Conductance	539	165.82	333.11	744.89	537.43	0.27	407.69	835.04	479	94	433	829
MMB-SW/SD-8	Sulfate as SO4	13.64	4.93	7.51	19.77	13.7	0.4	9.31	29.98	13	94	6.8	20.6
MMB-SW/SD-8A	Calcium, Dissolved	20.66	5.6	15.48	25.84	20.65	0.27	16.61	28.03	20	93	15	29
MMB-SW/SD-8A	Chloride	227	195.19	-15.36	469.36	220.42	0.74	116.6	2132.43	130	94	81	560
MMB-SW/SD-8A	Nitrogen, Ammonia	0.28	0.21	0.1	0.45	0.3	0.79	0.11	0.48	0.24	93	0.13	0.65
MMB-SW/SD-8A	Sodium, Dissolved	108.5	78.13	36.24	180.76	106.05	0.6	68.79	262.54	79	93	60.6	270
MMB-SW/SD-8A	Specific Conductance	780.8	570.68	72.2	1489.4	767.4	0.64	433.88	4461.78	517	94	318	1740
MMB-SW/SD-8A	Sulfate as SO4	15.54	4.15	11.7	19.38	15.63	0.32	12.11	22.87	15	93	14	20.2
MMB-SW/SD-9	Calcium, Dissolved	23.66	7.47	14.38	32.94	23.59	0.27	17.79	37.19	20.6	94	19	36.7
MMB-SW/SD-9	Nitrogen, Ammonia	0.57	0.4	0.07	1.07	0.56	0.61	0.33	2.7	0.37	94	0.3	1.24
MMB-SW/SD-9	Sodium, Dissolved	63.84	26.26	31.23	96.45	63.44	0.35	45.03	119.06	53	94	45.2	110
MMB-SW/SD-9	Specific Conductance	459.8	146.92	277.38	642.22	458.24	0.27	345.56	722.78	394	94	364	719
MMB-SW/SD-9	Sulfate as SO4	10.9	5.1	4.57	17.23	10.93	0.5	6.88	33.42	9.6	94	5.1	16.4

Note: All units expressed in mg/L except for Specific Conductance (umhos/cm)
LCL = Lower Confidence Limit
UCL = Upper Confidence Limit
CV = Coefficient of Variation
CI = Achieved Level of Confidence (%)
Calculations represent all historical data.

Figures



GEOMEGA

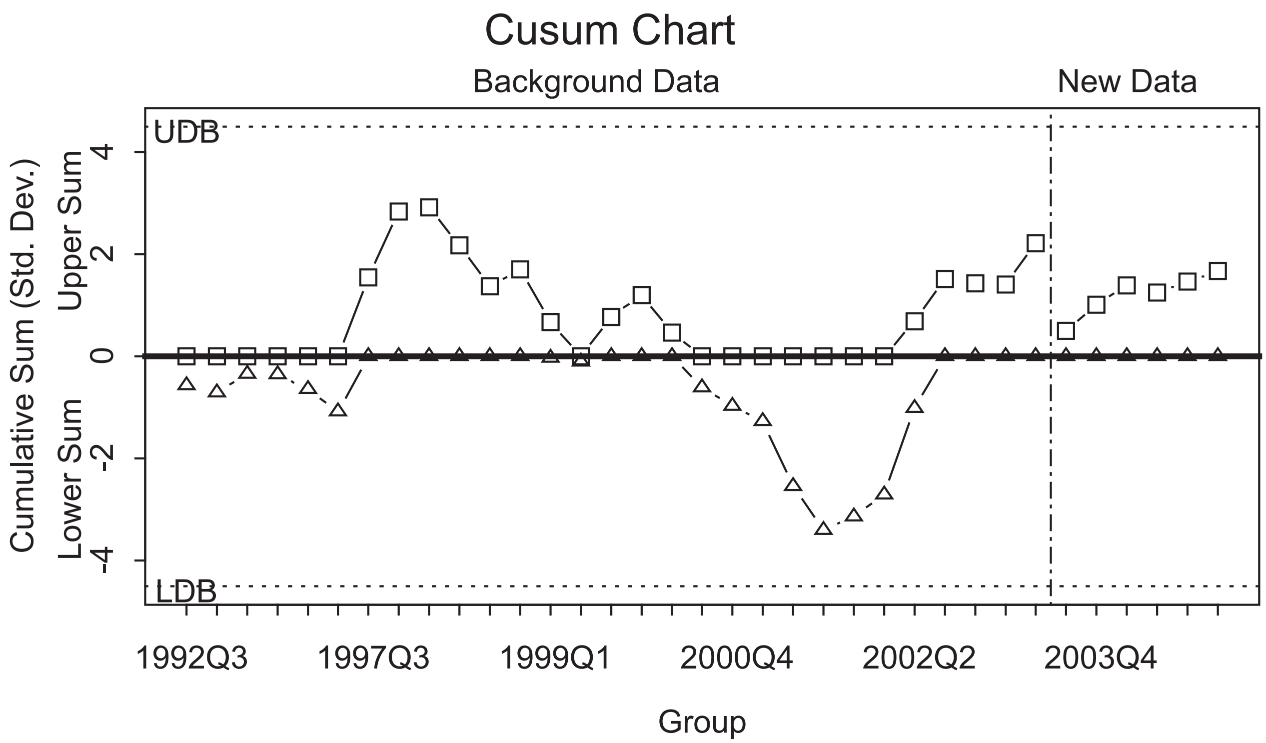
8/2/05

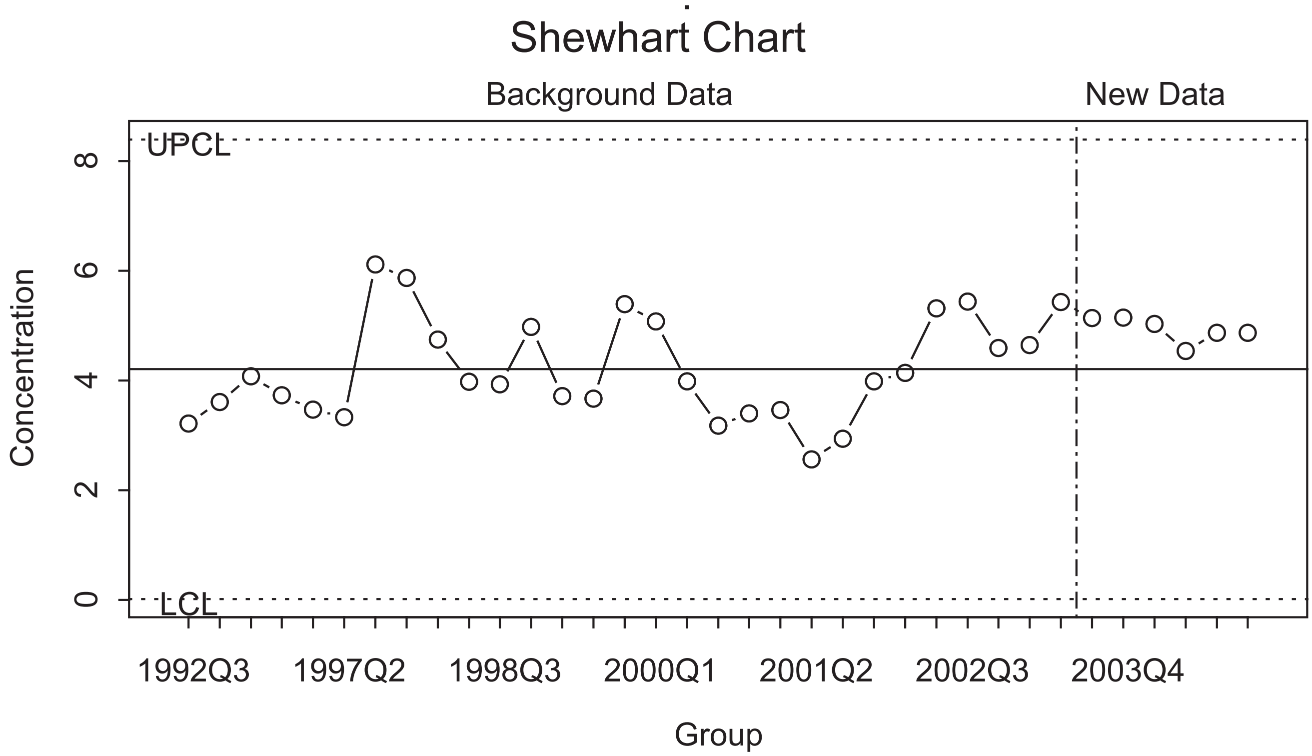
C0303B
Olin

Sampling locations in the Western Bedrock Valley monitoring program.

Figure 1

JJ S:\Olin\ProductionData\apr_mxd\samp_loc_wbv





GEOMEGA

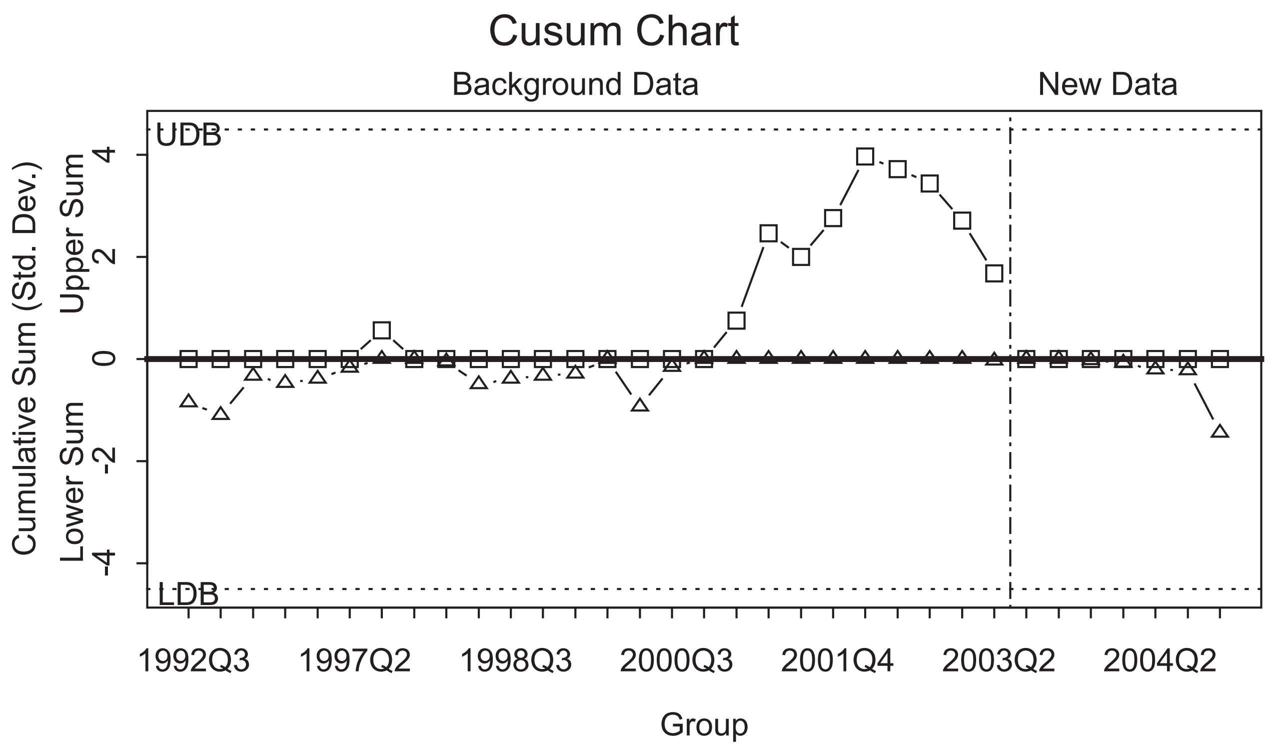
8/4/05

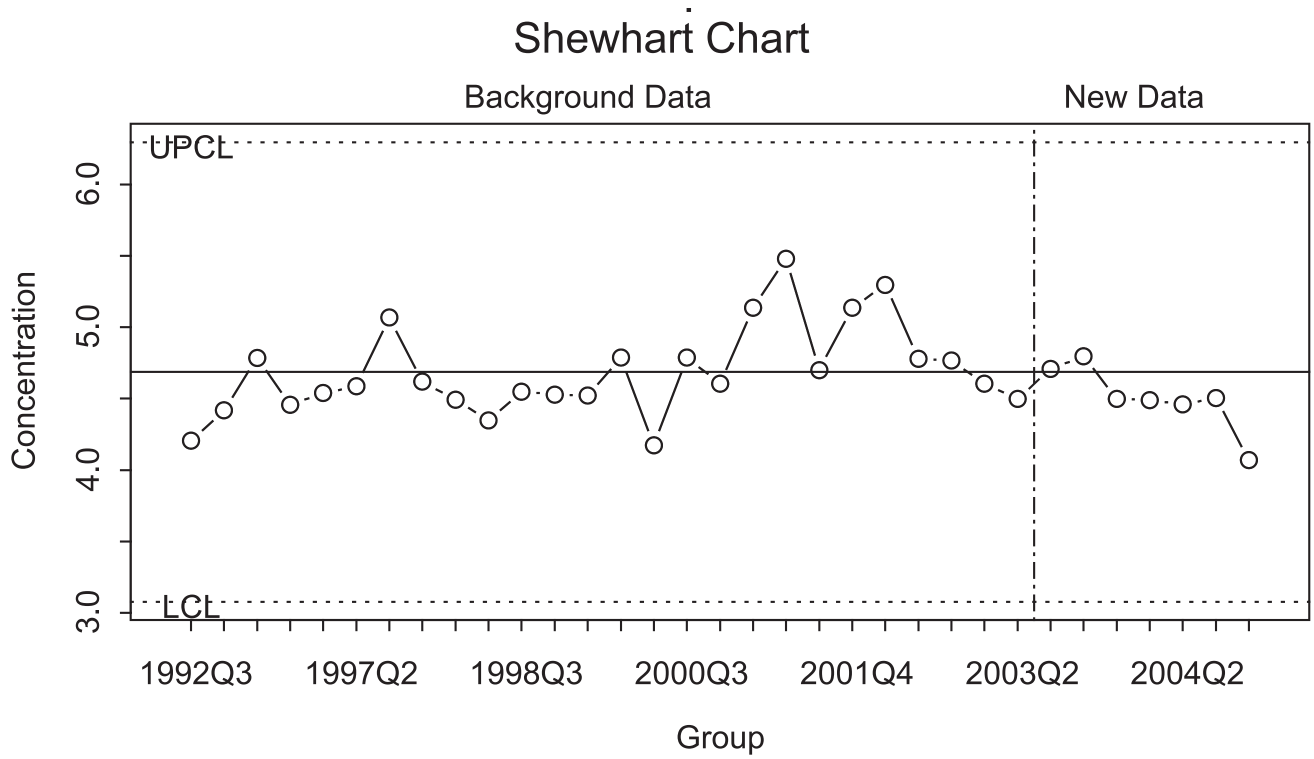
C03302C
Olin-Wilmington

Control charts for GW-63D sulfate as SO_4 log (mg/L).

Figure
2

JM o:\Olin\Statistical Analysis\GW-63D SO4.ai





GEOMEGA

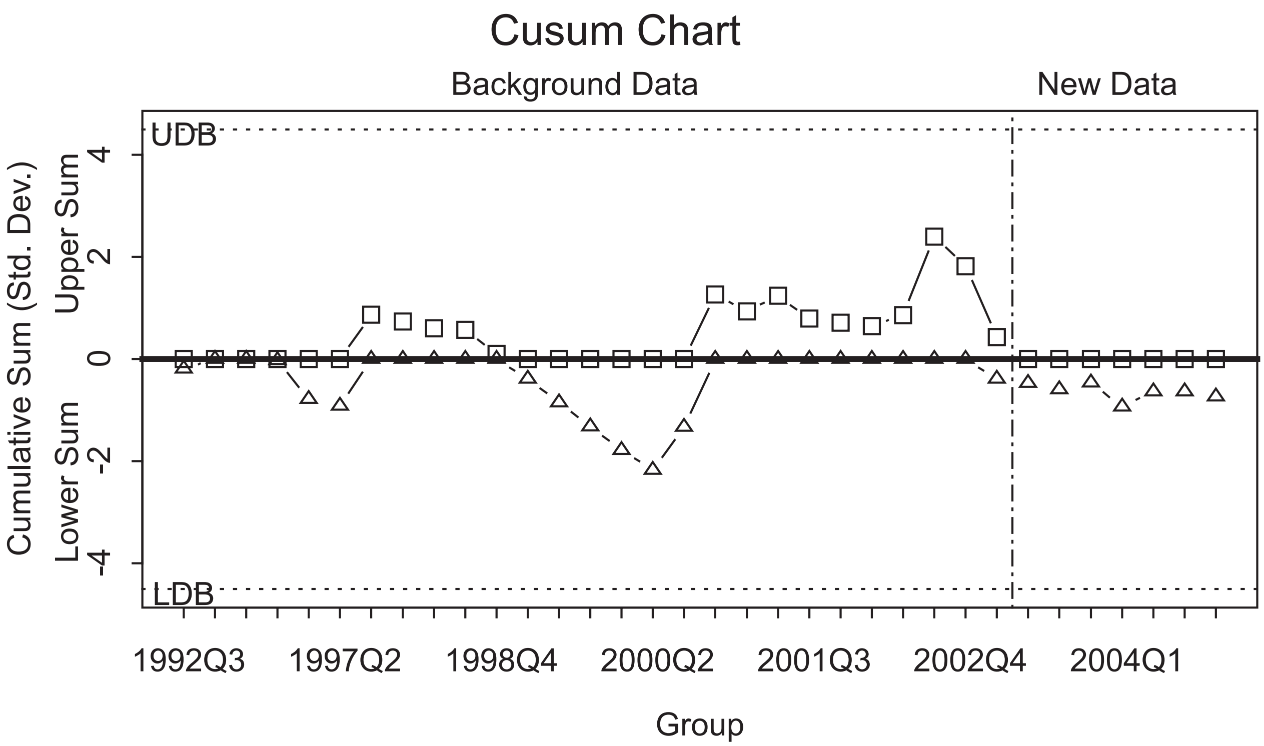
8/4/05

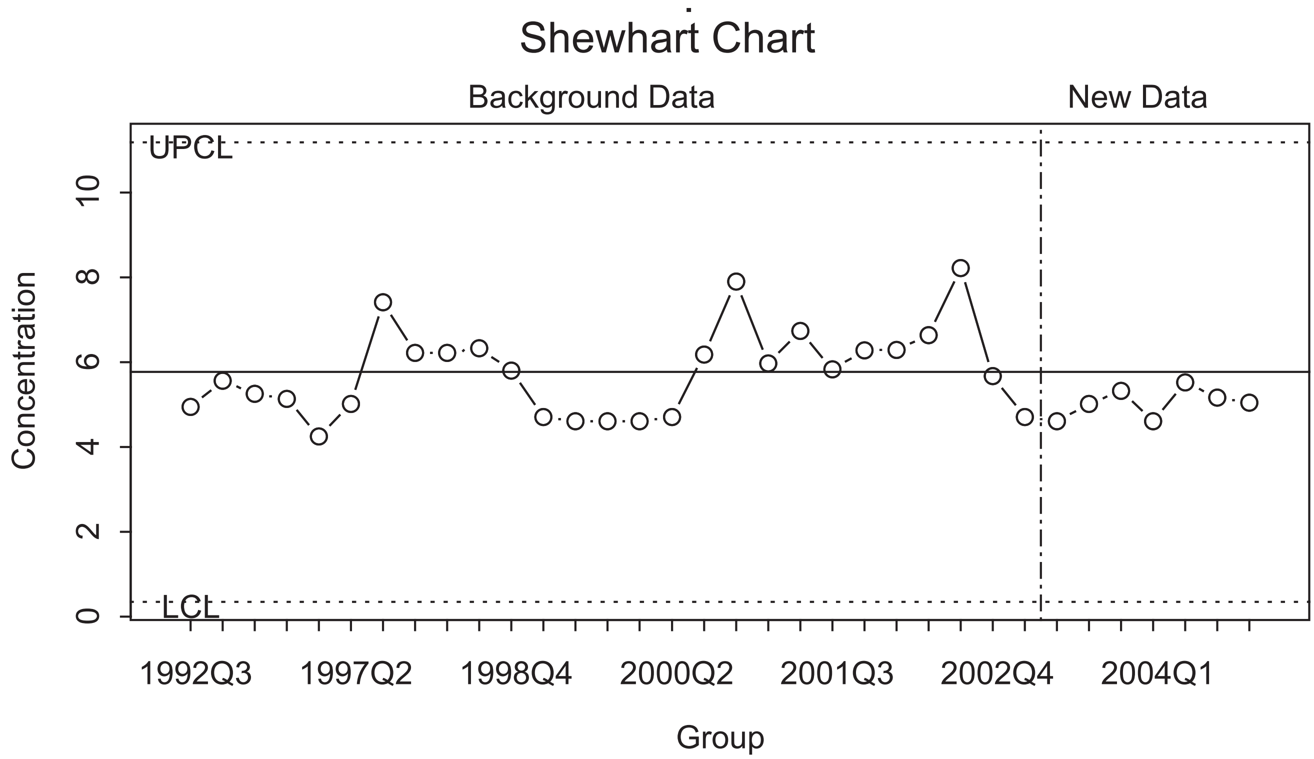
C03302C
Olin-Wilmington

Control charts for GW-63S chloride log (mg/L).

Figure
3

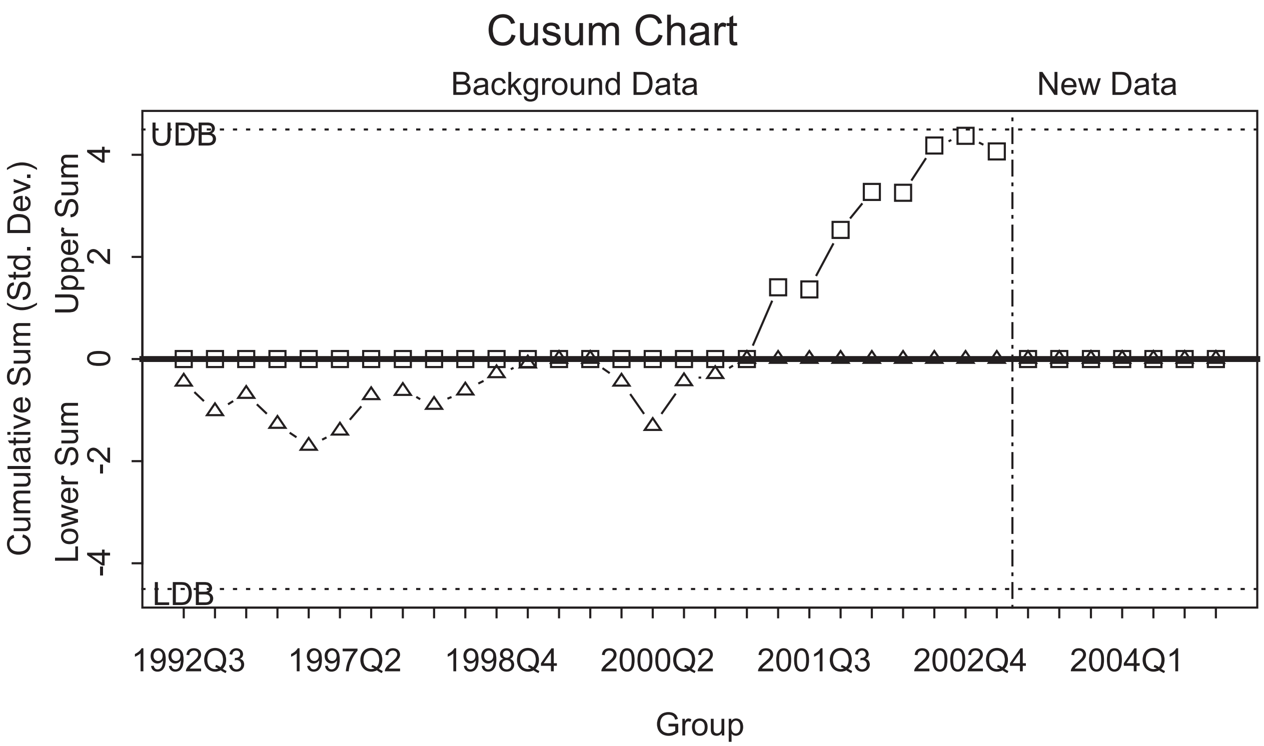
JM o:\Olin\Statistical Analysis\GW-63S Cl.ai

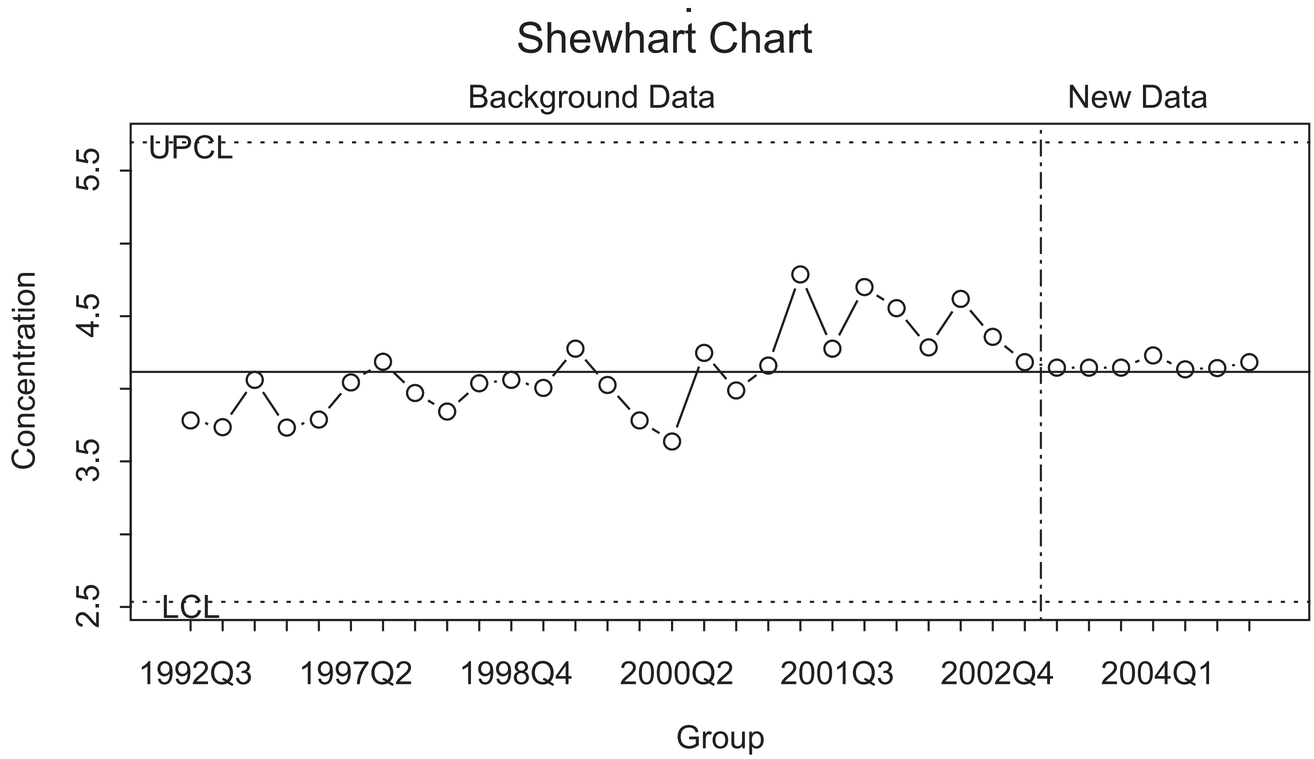




GEOMEGA 8/4/05 C03302C Olin-Wilmington	Control charts for GW-63S nitrogen, ammonia log (µg/L).	**Figure** 4

JM o:\Olin\Statistical Analysis\GW-63S NH3.ai





GEOMEGA

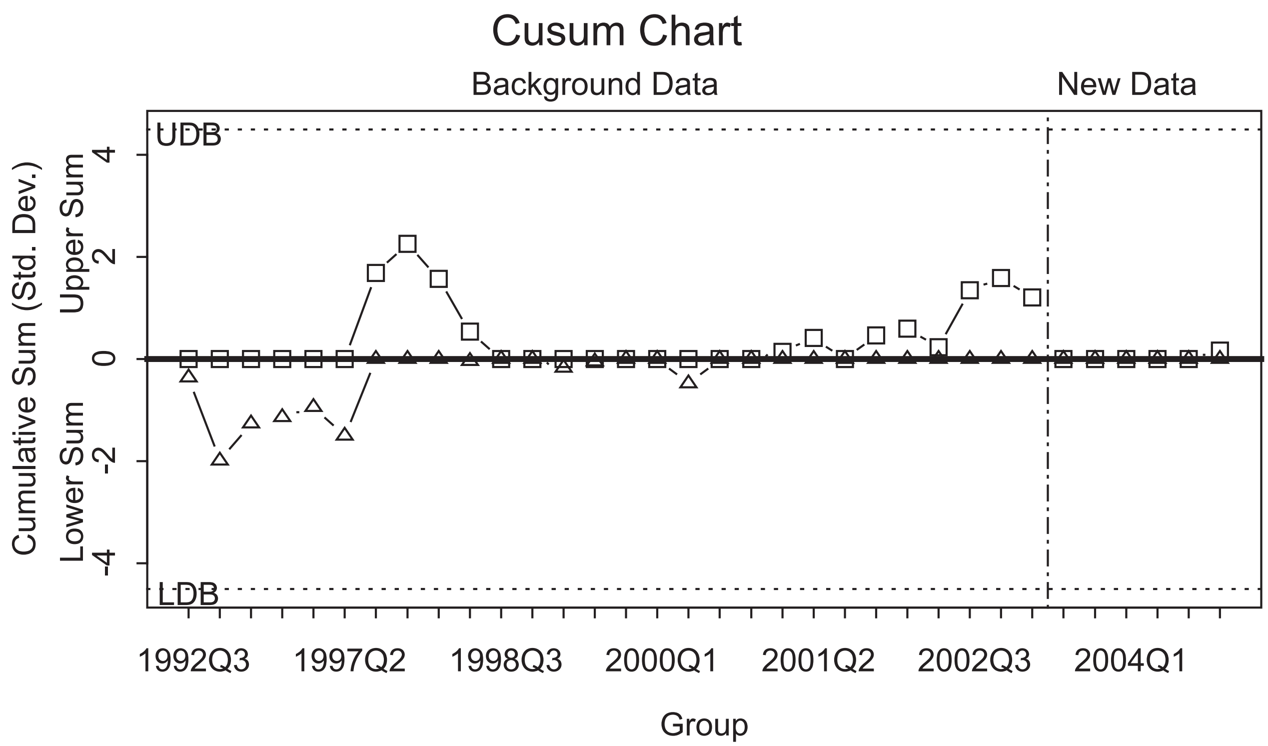
8/4/05

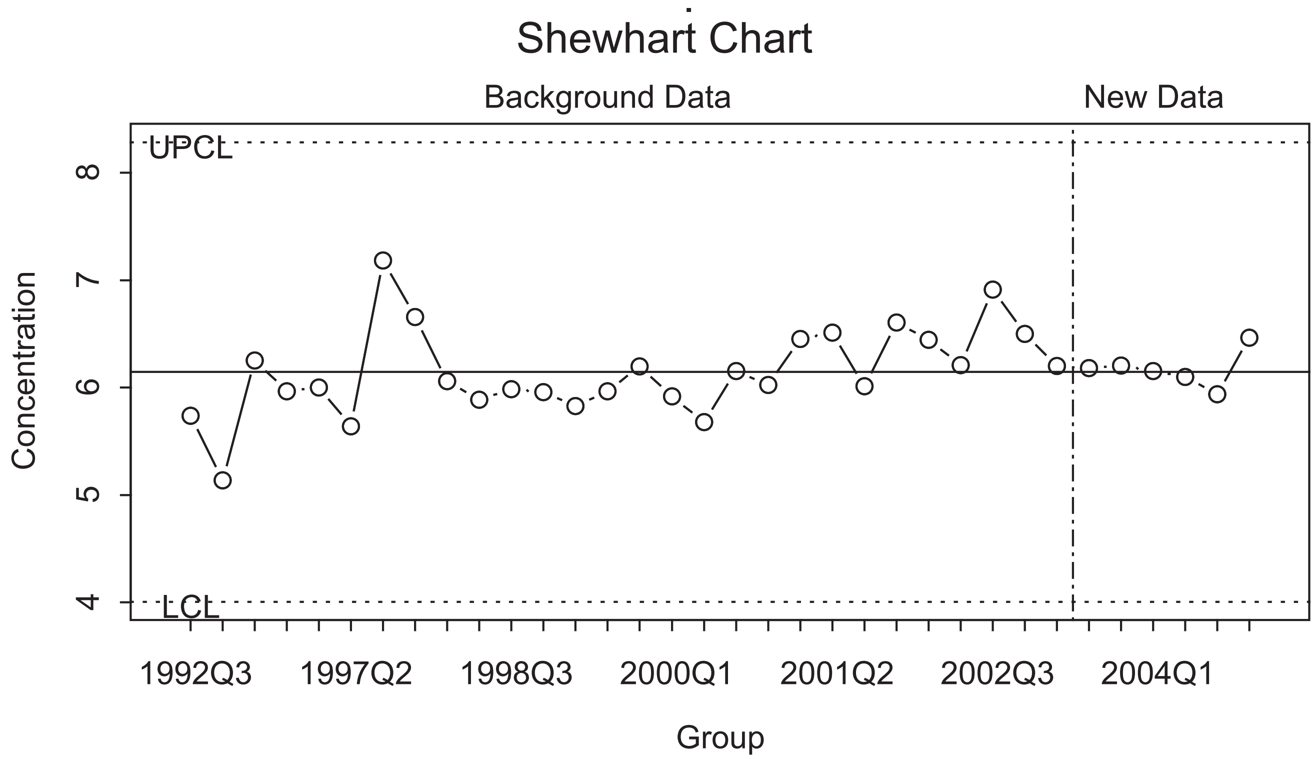
C03302C
Olin-Wilmington

Control charts for GW-63S sodium, dissolved log (mg/L).

Figure
5

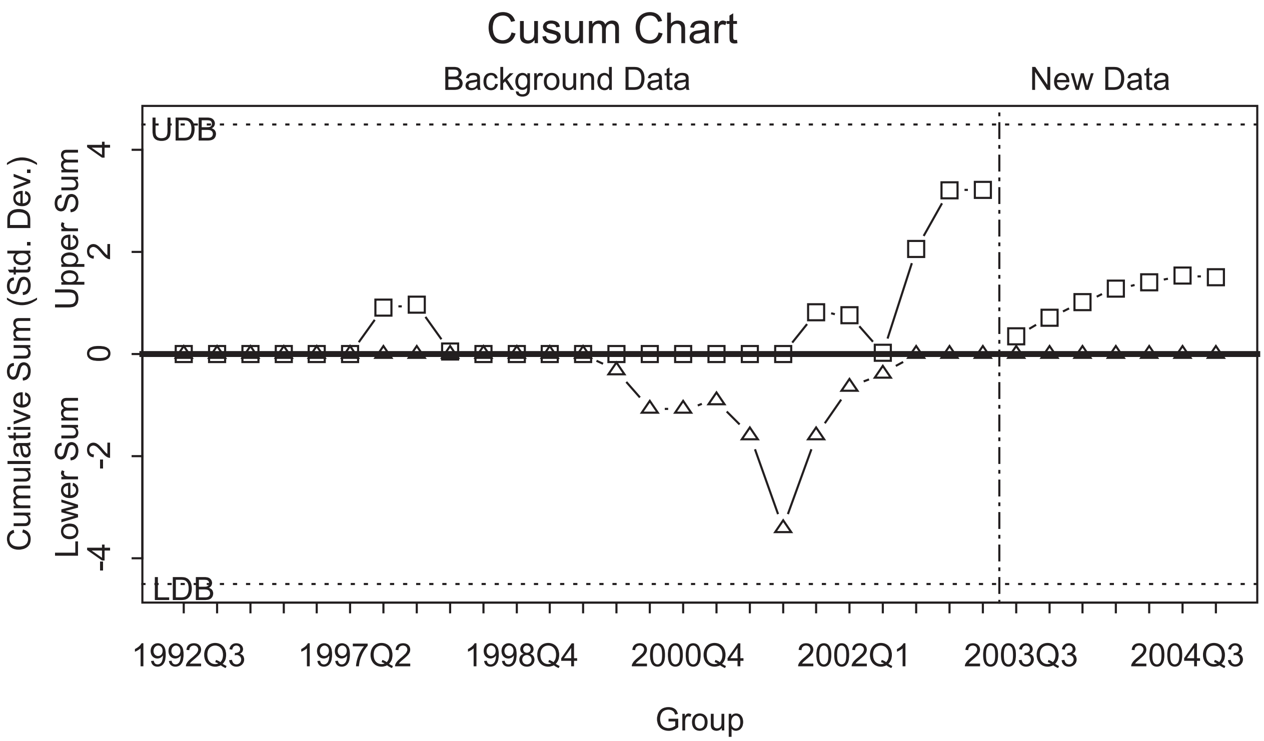
JM o:\Olin\Statistical Analysis\GW-63S Na.ai

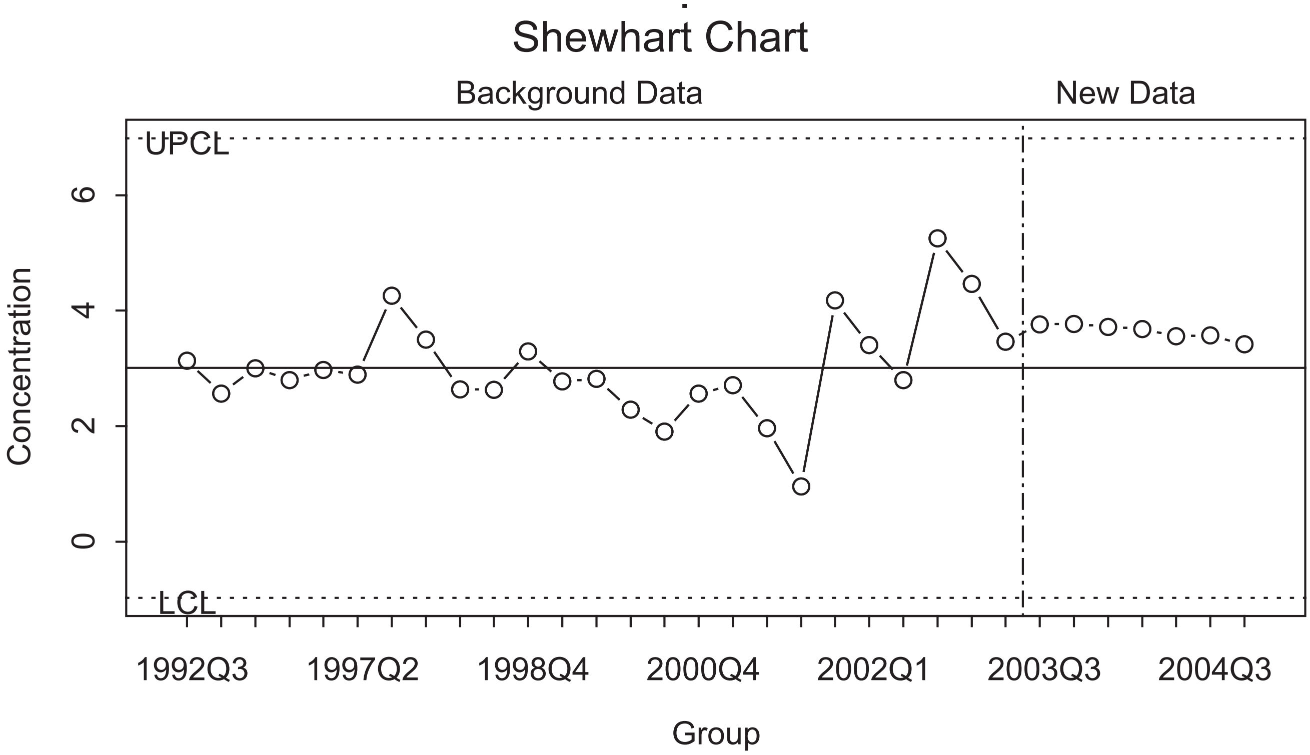




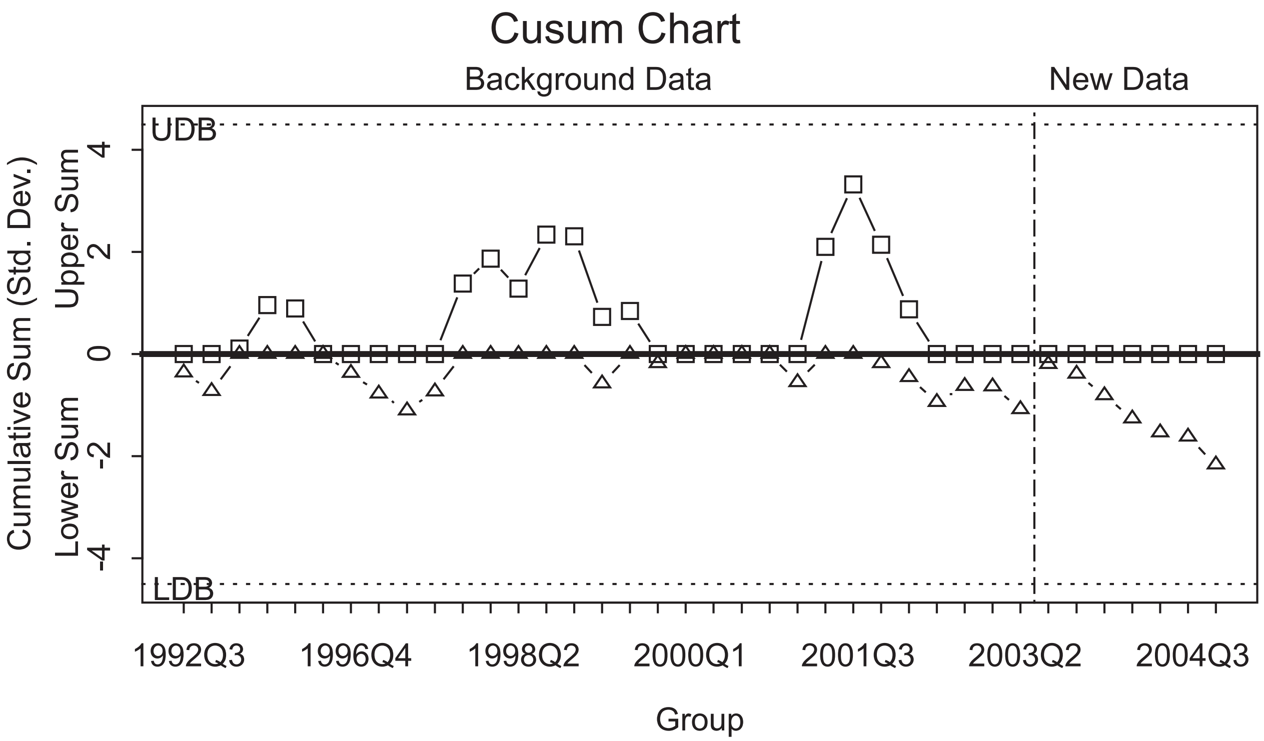
GEOMEGA 8/4/05 C03302C Olin-Wilmington	Control charts for GW-63S specific conductance log (mg/L).	**Figure** 6

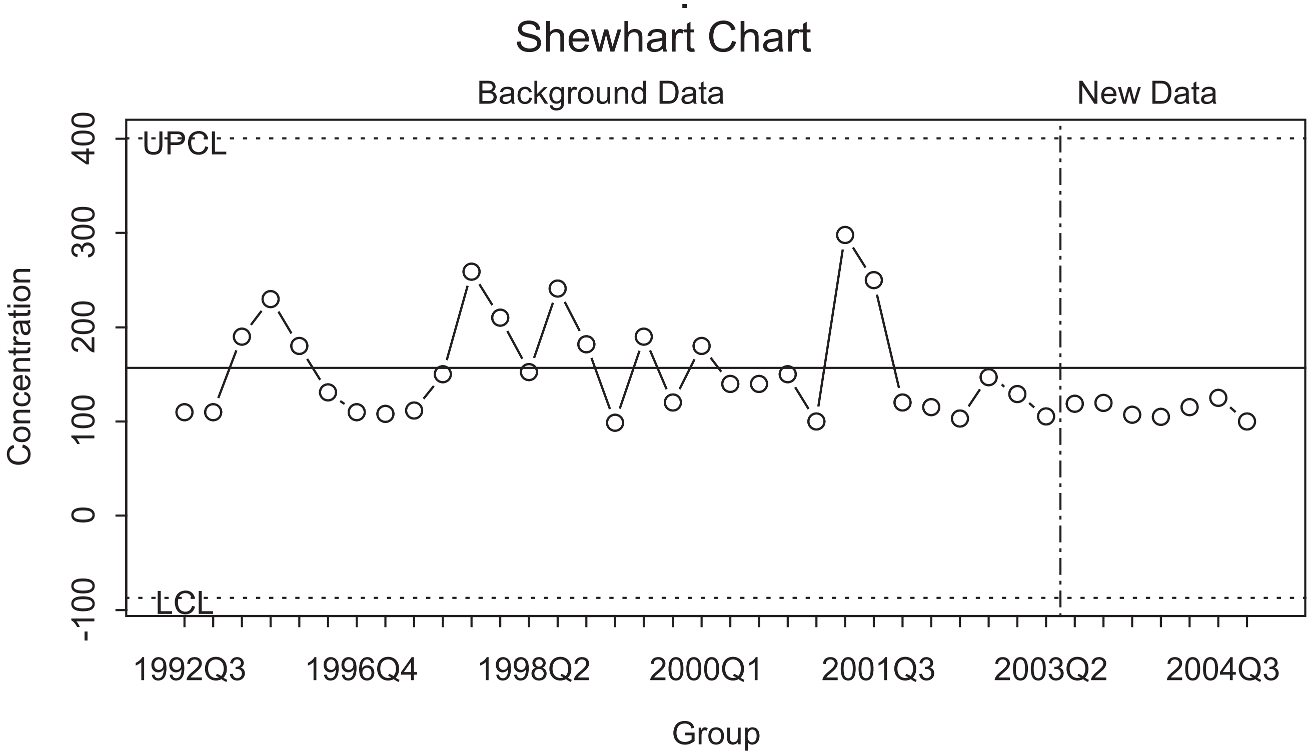
JM o:\Olin\Statistical Analysis\GW-63S SC.ai





GEOMEGA 8/4/05 C03302C Olin-Wilmington	Control charts for GW-63S sulfate as SO_4 log (mg/L).	**Figure** 7





GEOMEGA

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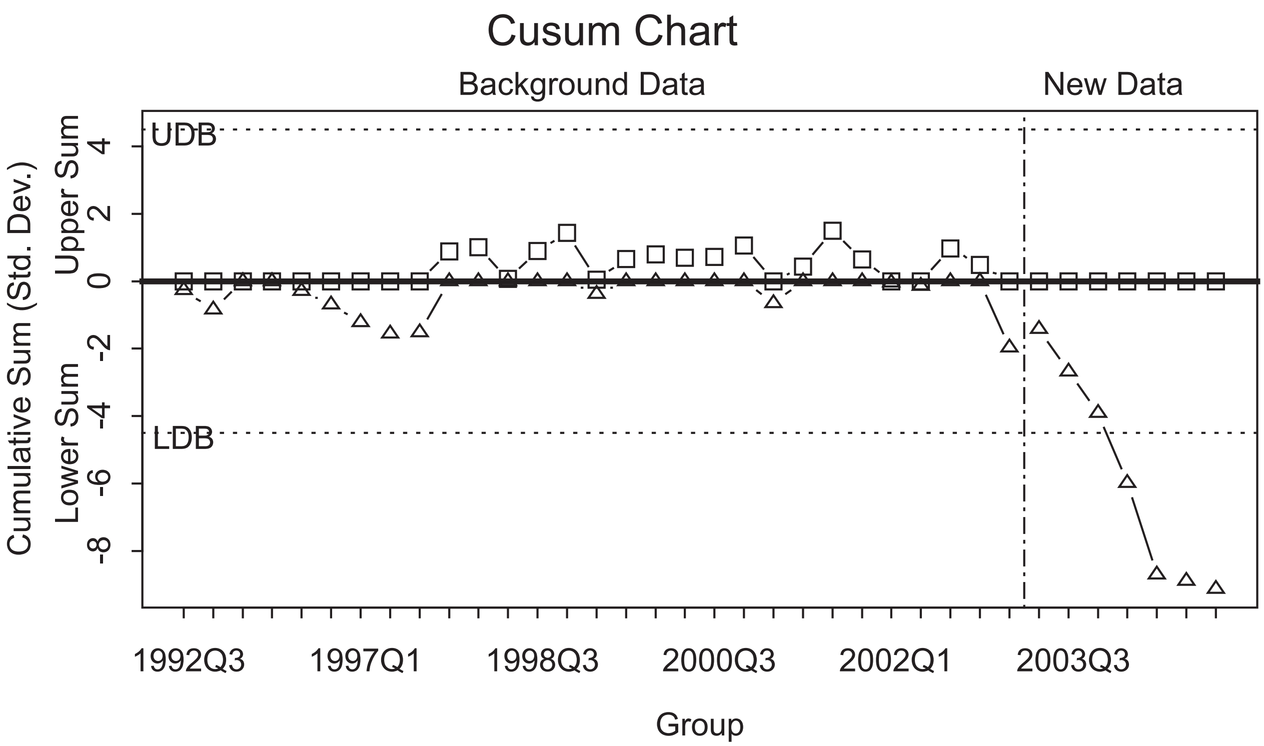
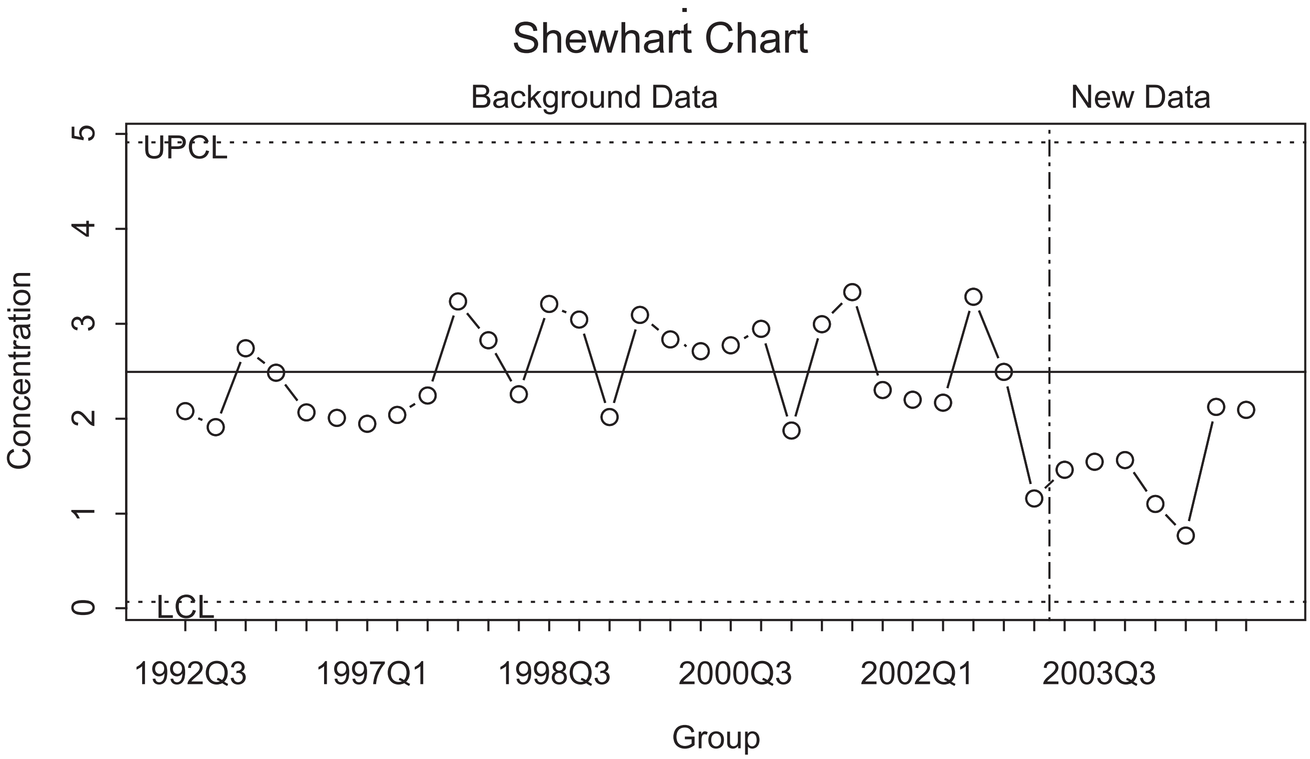
C03302C
Olin-Wilmington

Control charts for GW-64D chloride (mg/L).

Figure
8

JM o:\Olin\Statistical Analysis\GW-64D Cl.ai





GEOMEGA

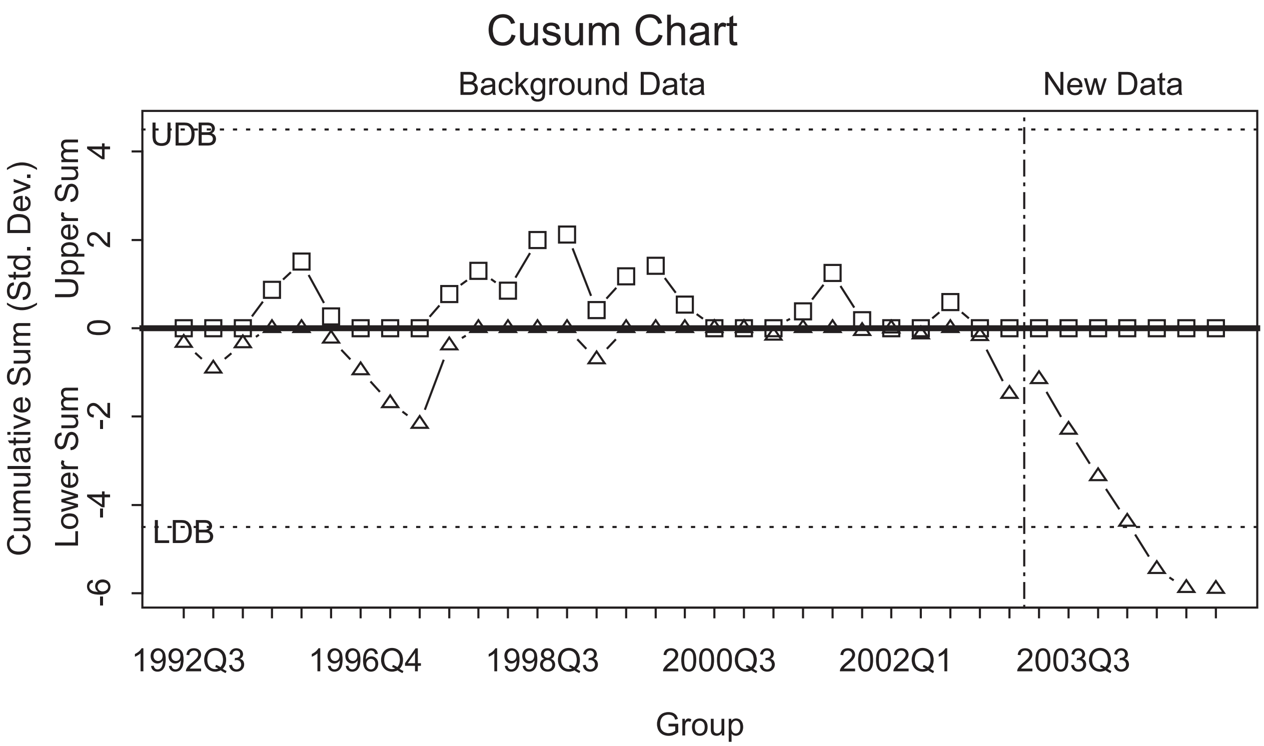
8/4/05

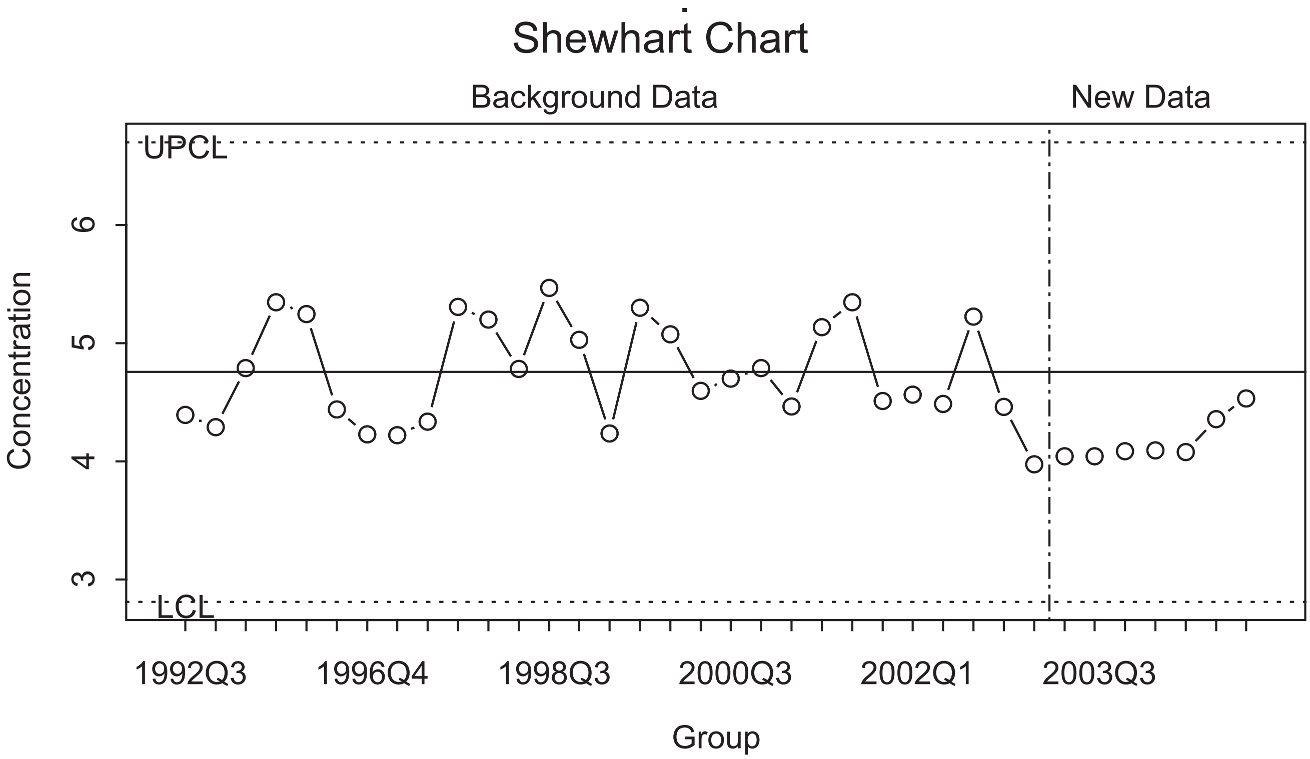
C03302C
Olin-Wilmington

Control charts for GW-64D nitrogen, ammonia log (mg/L).

Figure
9

JM o:\Olin\Statistical Analysis\GW-64D NH3.ai





GEOMEGA

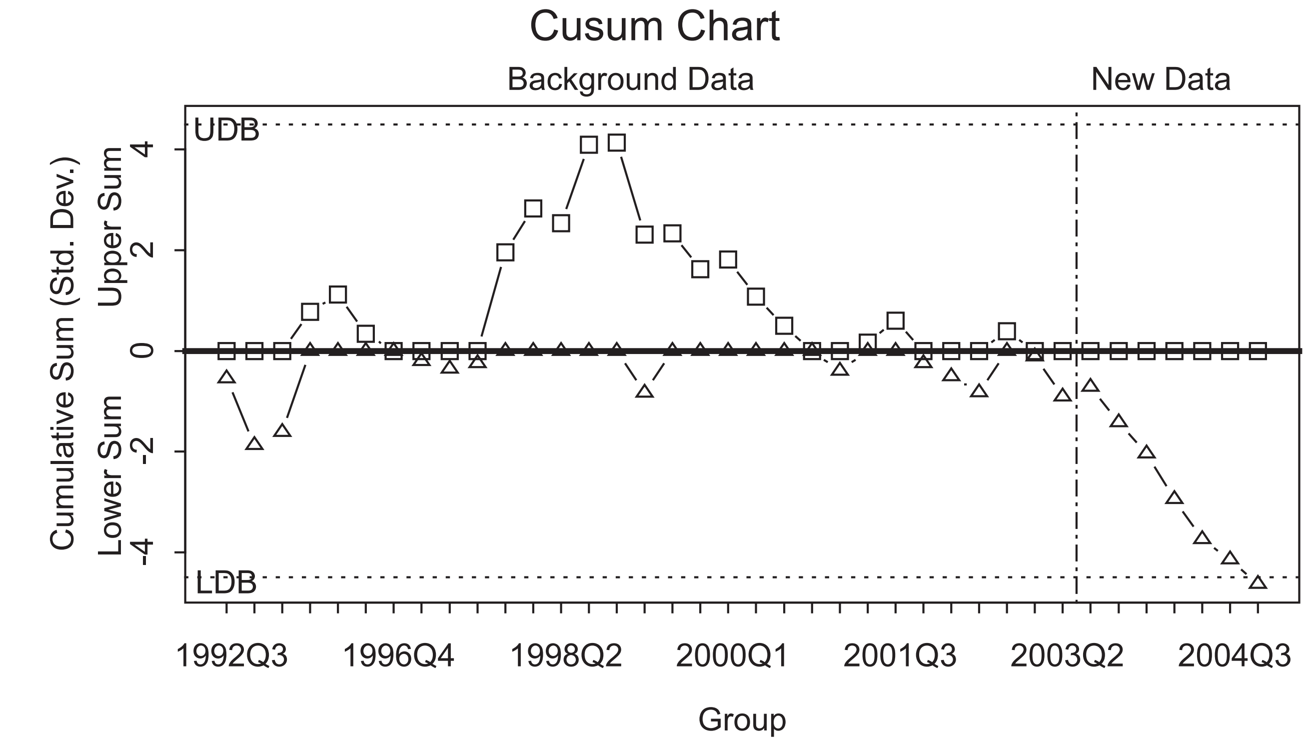
8/4/05

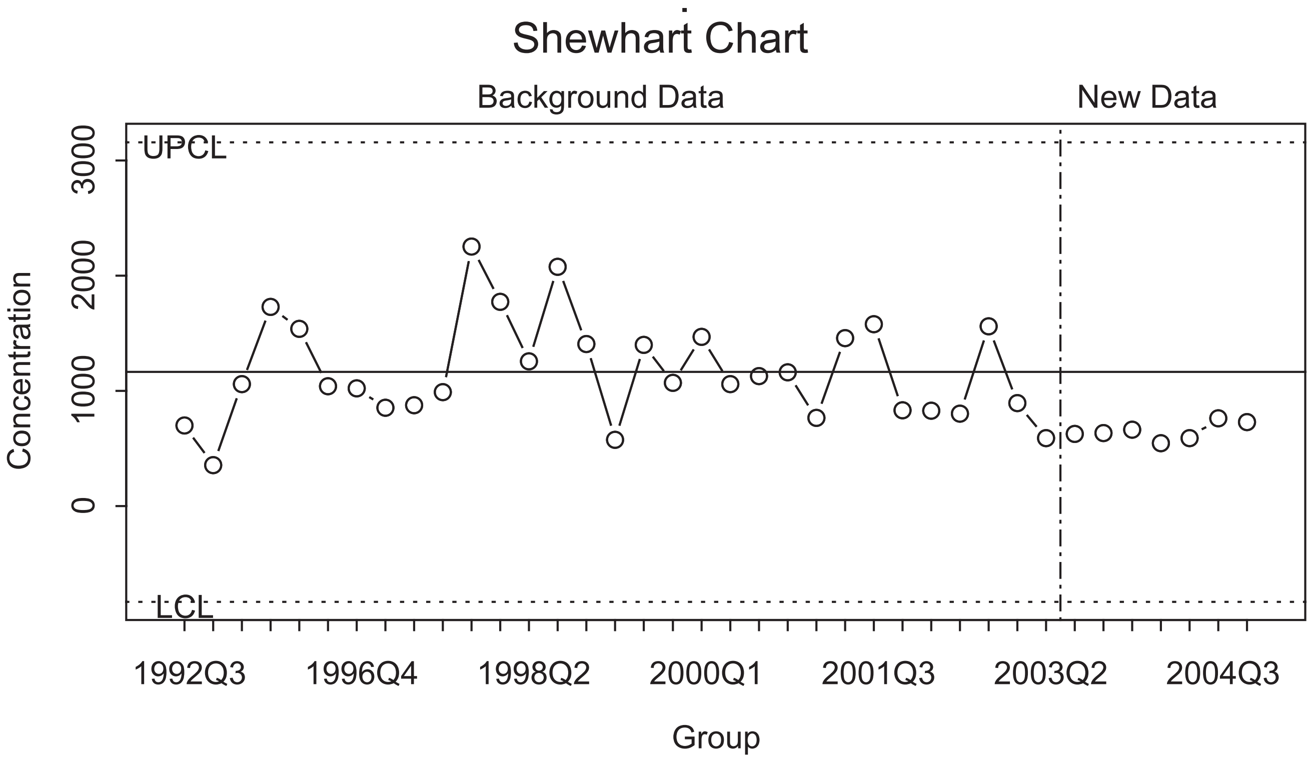
C03302C
Olin-Wilmington

Control charts for GW-64D sodium, dissolved log (mg/L).

Figure
10

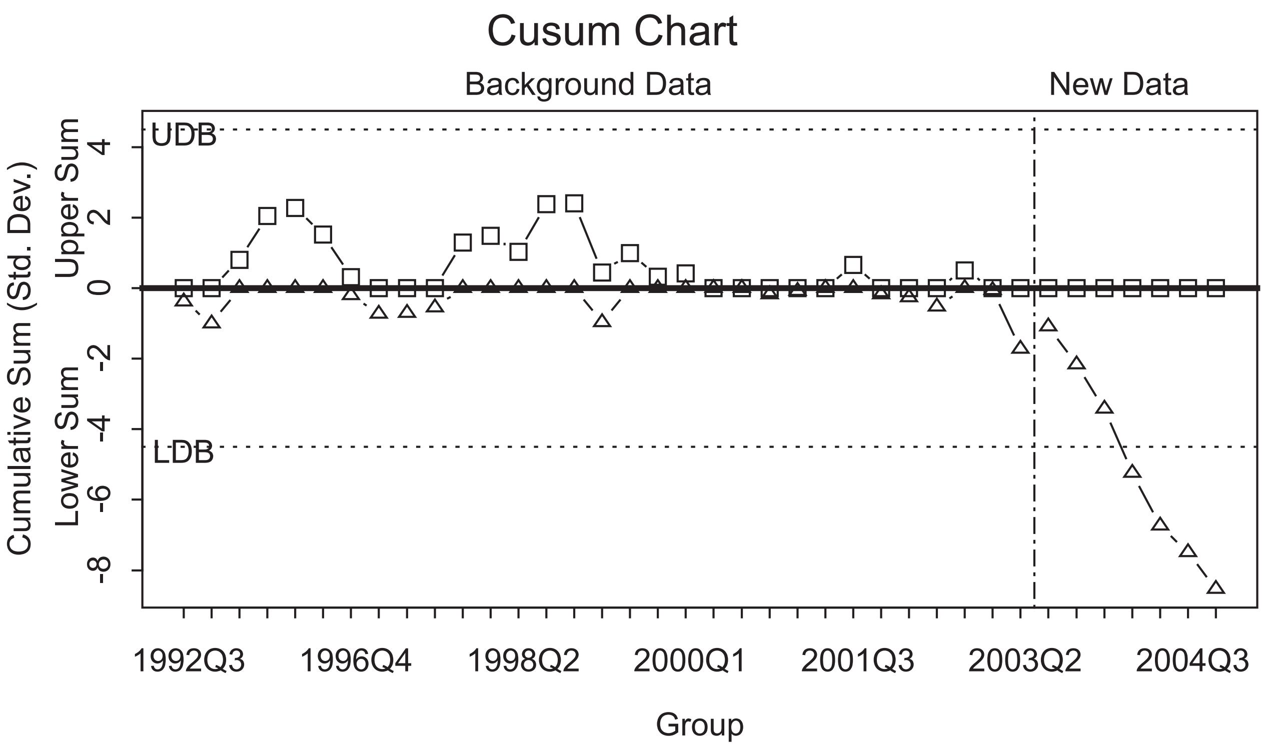
JM o:\Olin\Statistical Analysis\GW-64D Na.ai

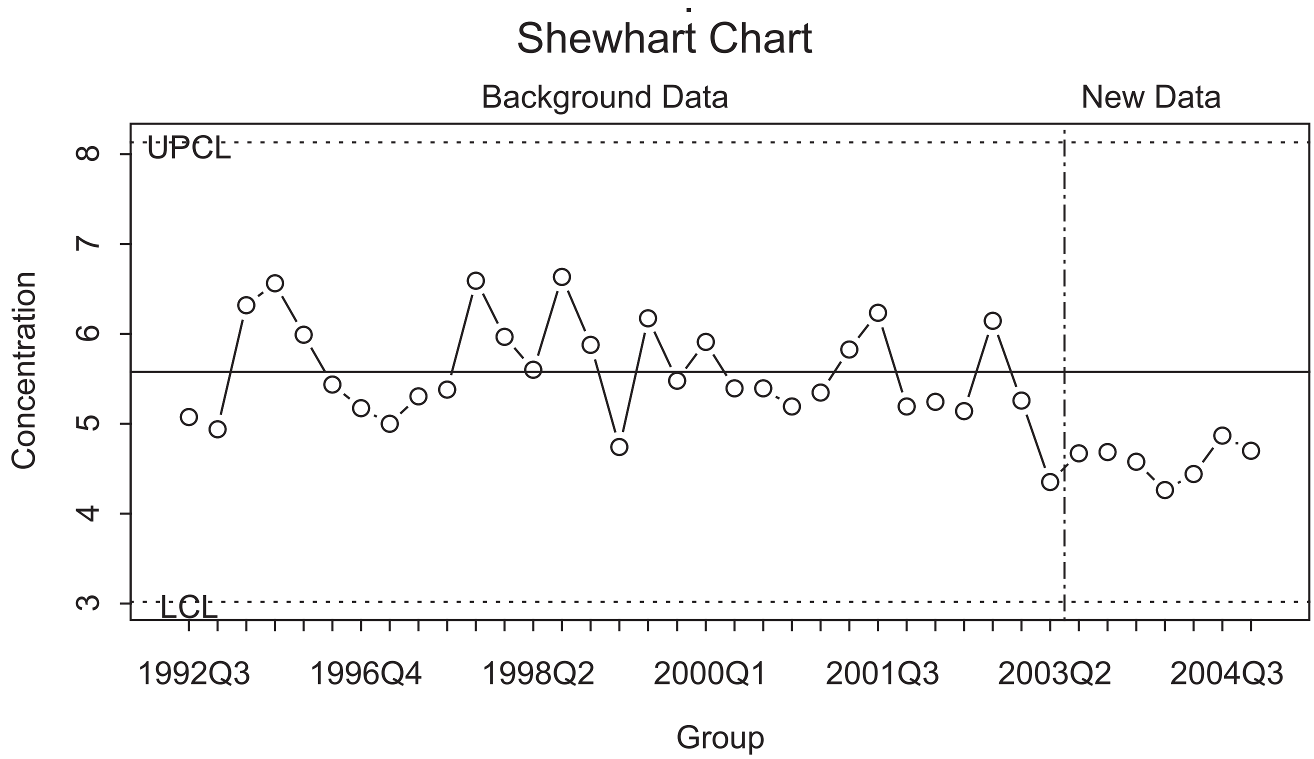




GEOMEGA 8/4/05 C03302C Olin-Wilmington	Control charts for GW-64D specific conductance (µmhos/cm).	**Figure** 11

JM o:\Olin\Statistical Analysis\GW-64D SC.ai





GEOMEGA

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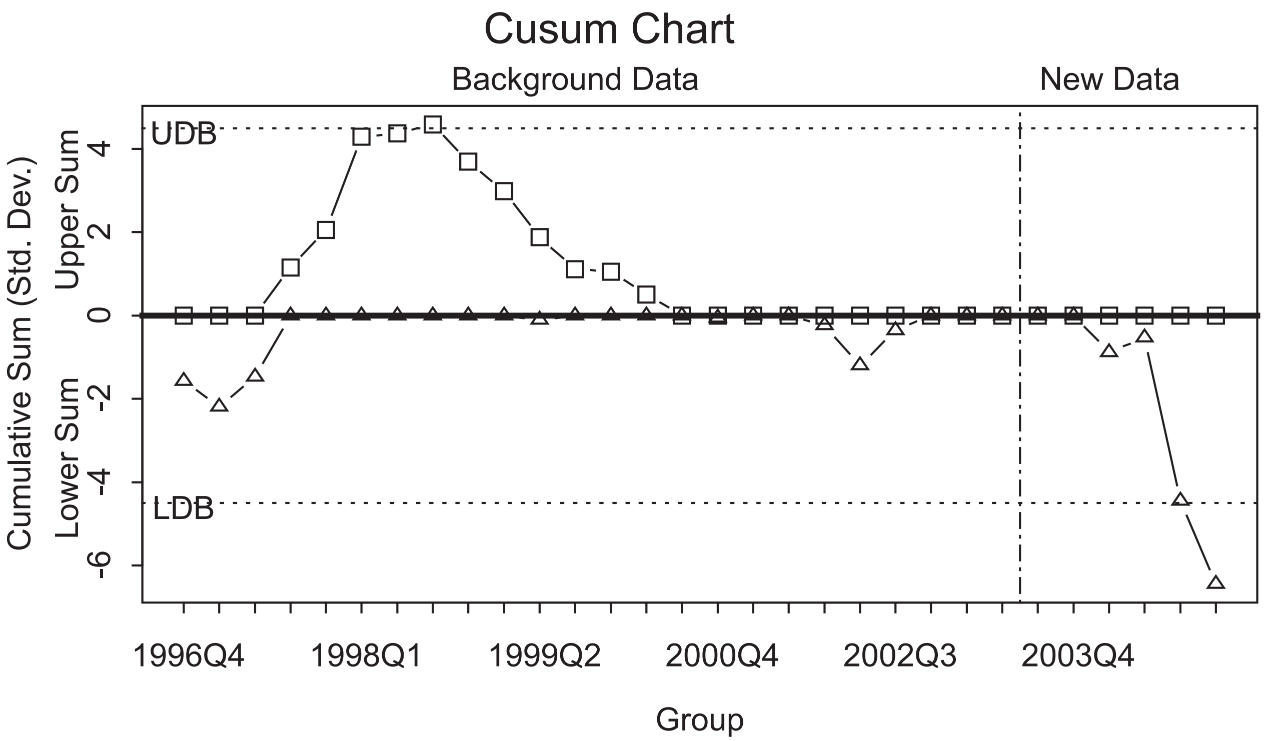
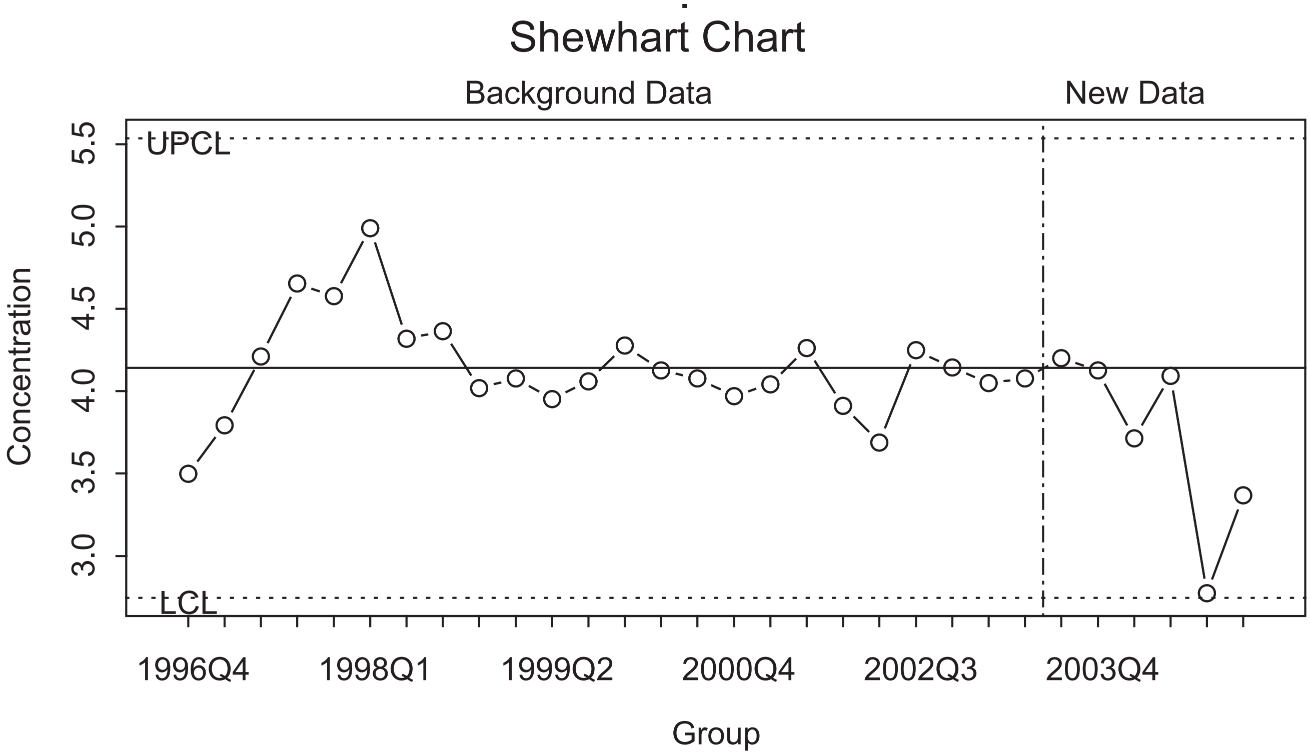
C03302C
Olin-Wilmington

Control charts for GW-64D sulfate as SO_4 log (mg/L).

Figure
12

JM o:\Olin\Statistical Analysis\GW-64D SO4.ai





GEOMEGA

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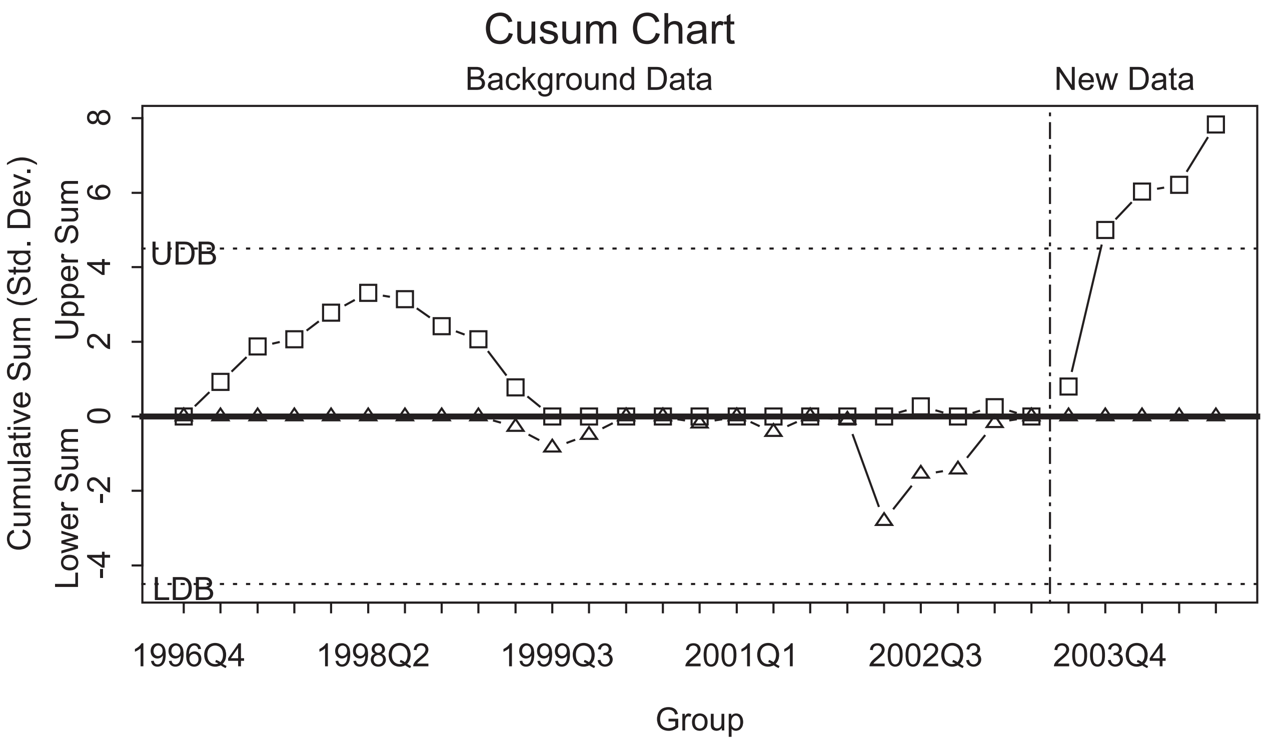
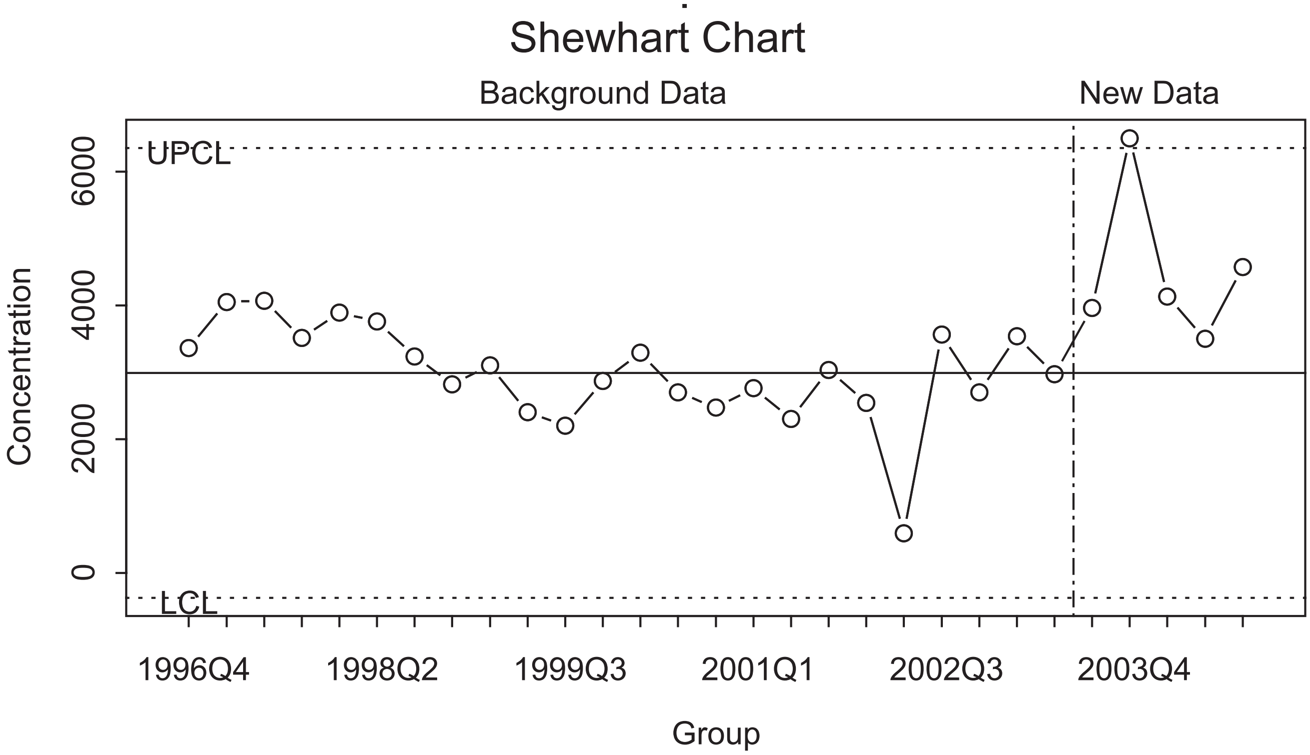
C03302C
Olin-Wilmington

Control charts for GW-86M sulfate as SO_4 log (mg/L).

Figure
13

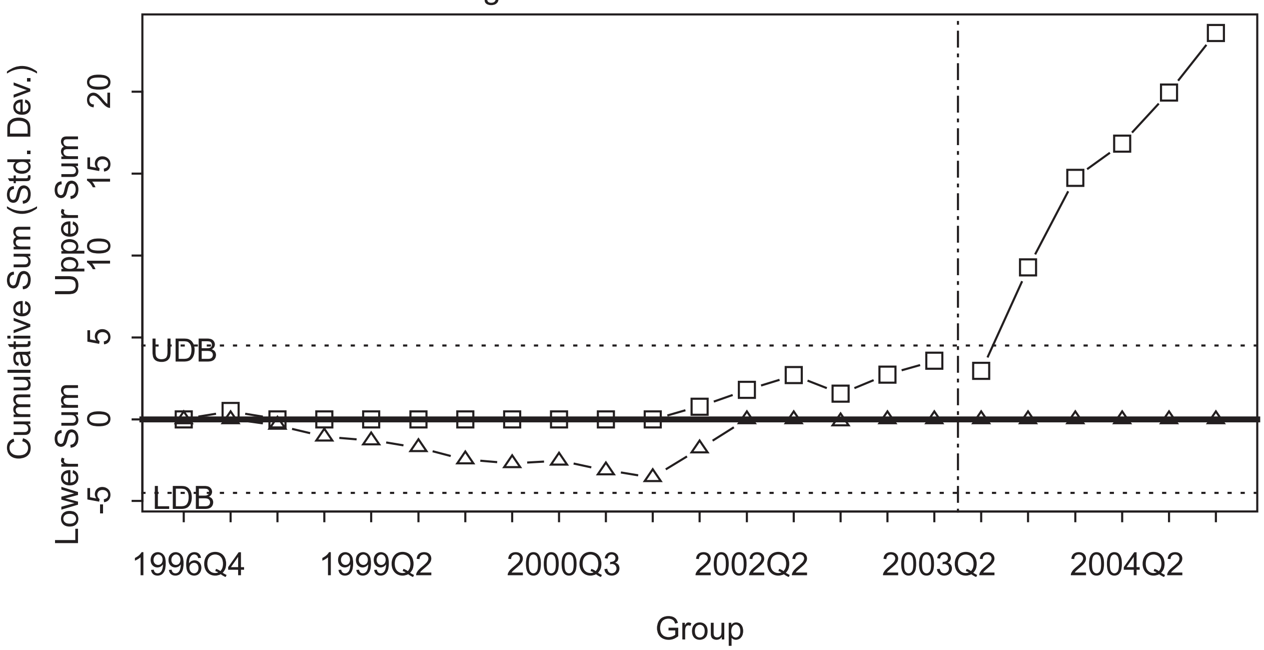
JM o:\Olin\Statistical Analysis\GW-86M SO4.ai



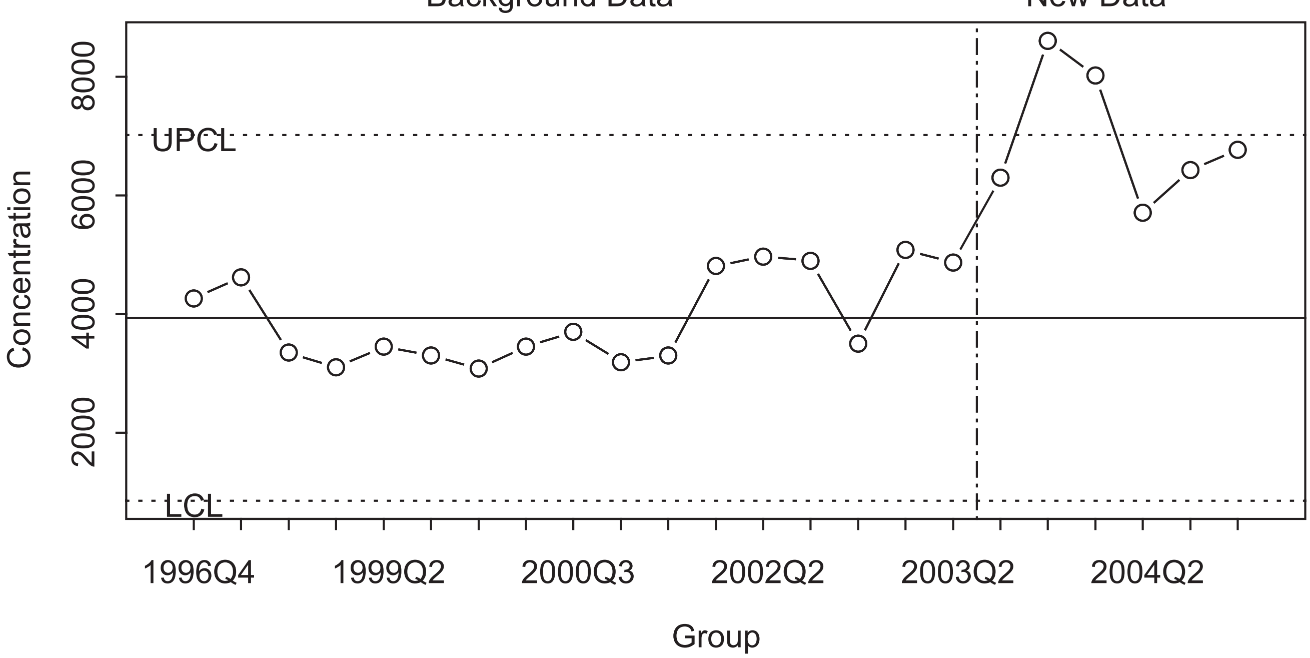


GEOMEGA 8/4/05 C03302C Olin-Wilmington	Control charts for GW-86D specific conductance log (µmhos/cm).	**Figure** 14

Cusum Chart



Shewhart Chart



GEOMEGA

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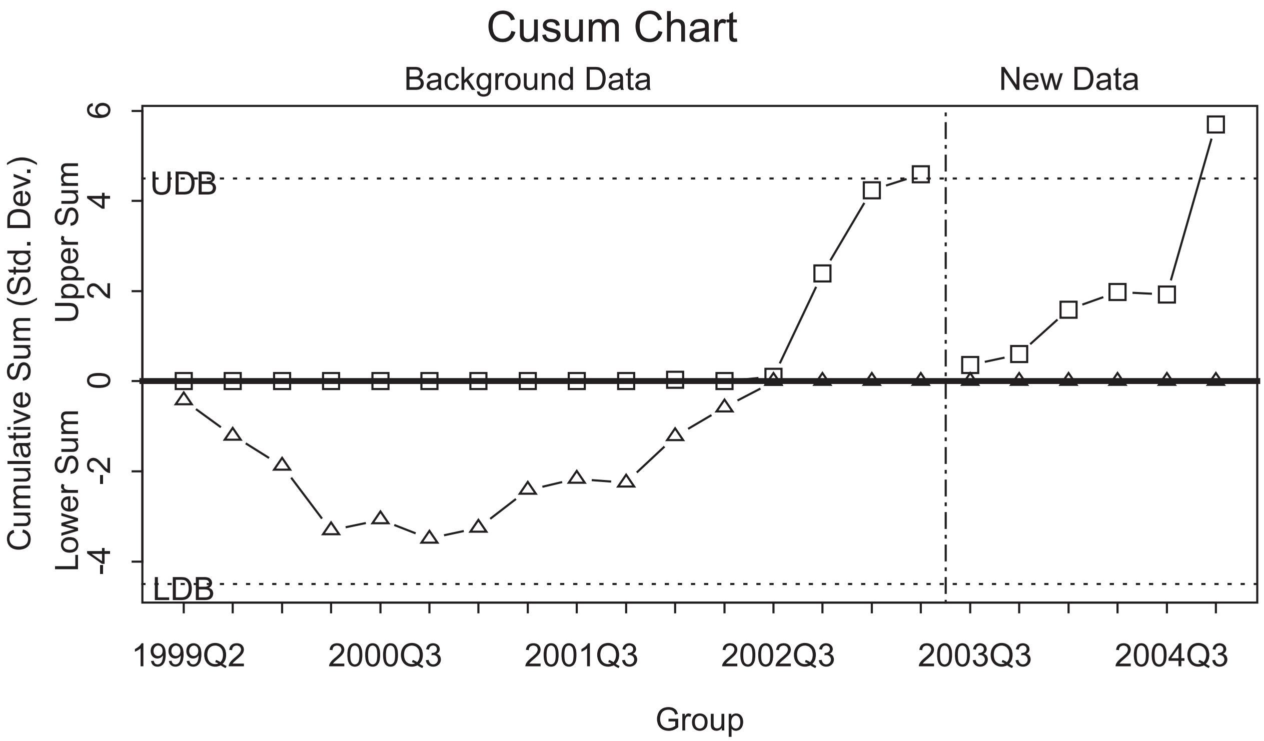
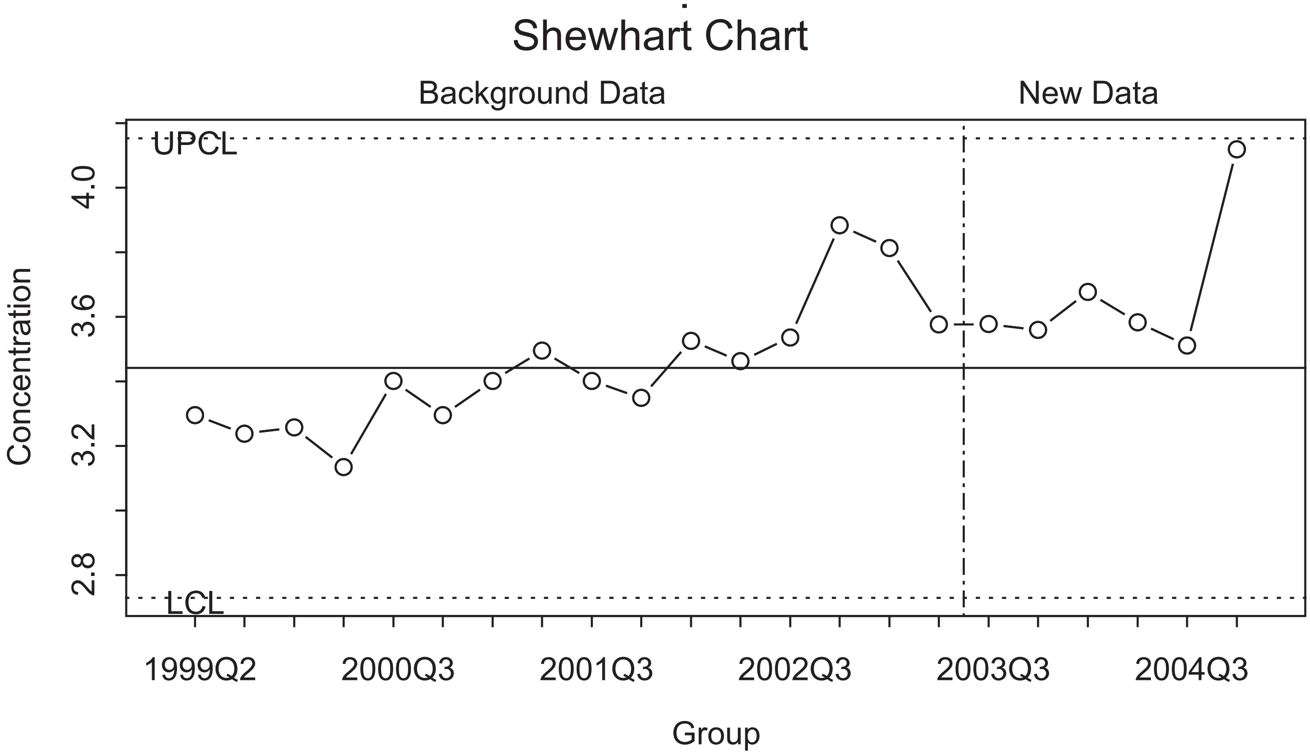
C03302C
Olin-Wilmington

Control charts for GW-87D specific conductance (µmhos/cm).

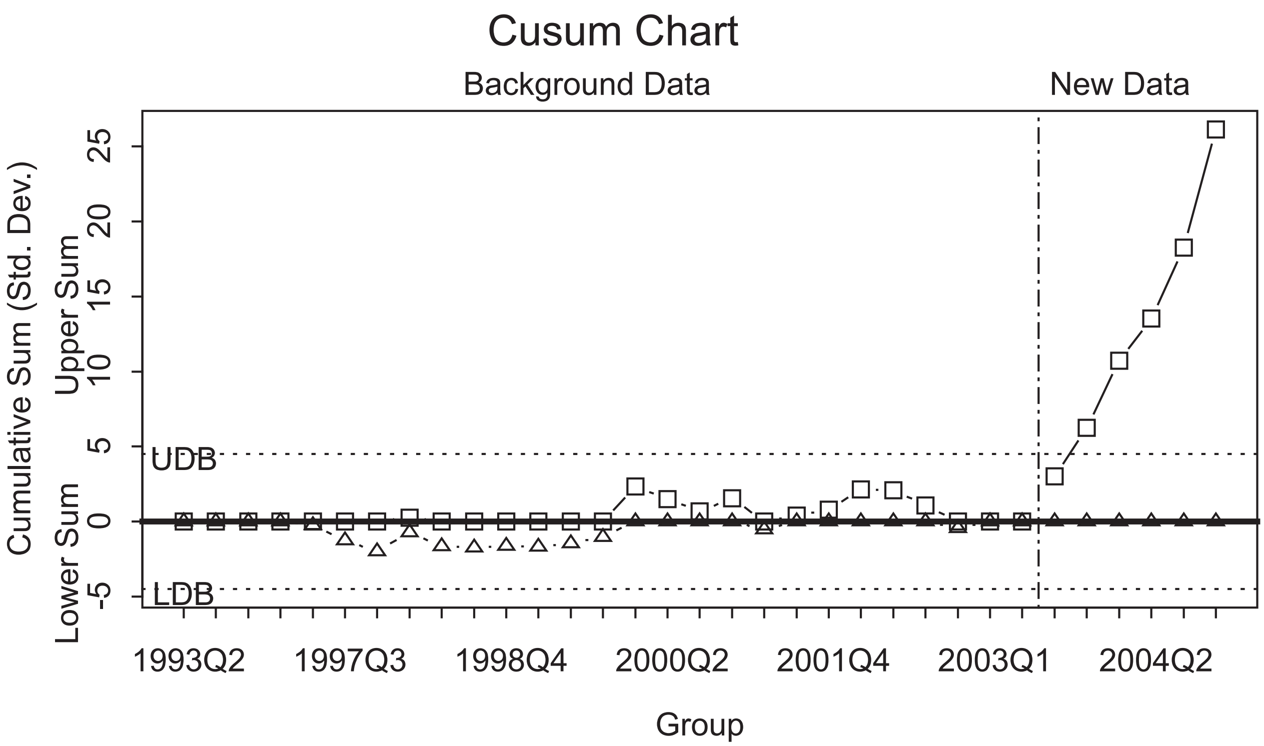
Figure
15

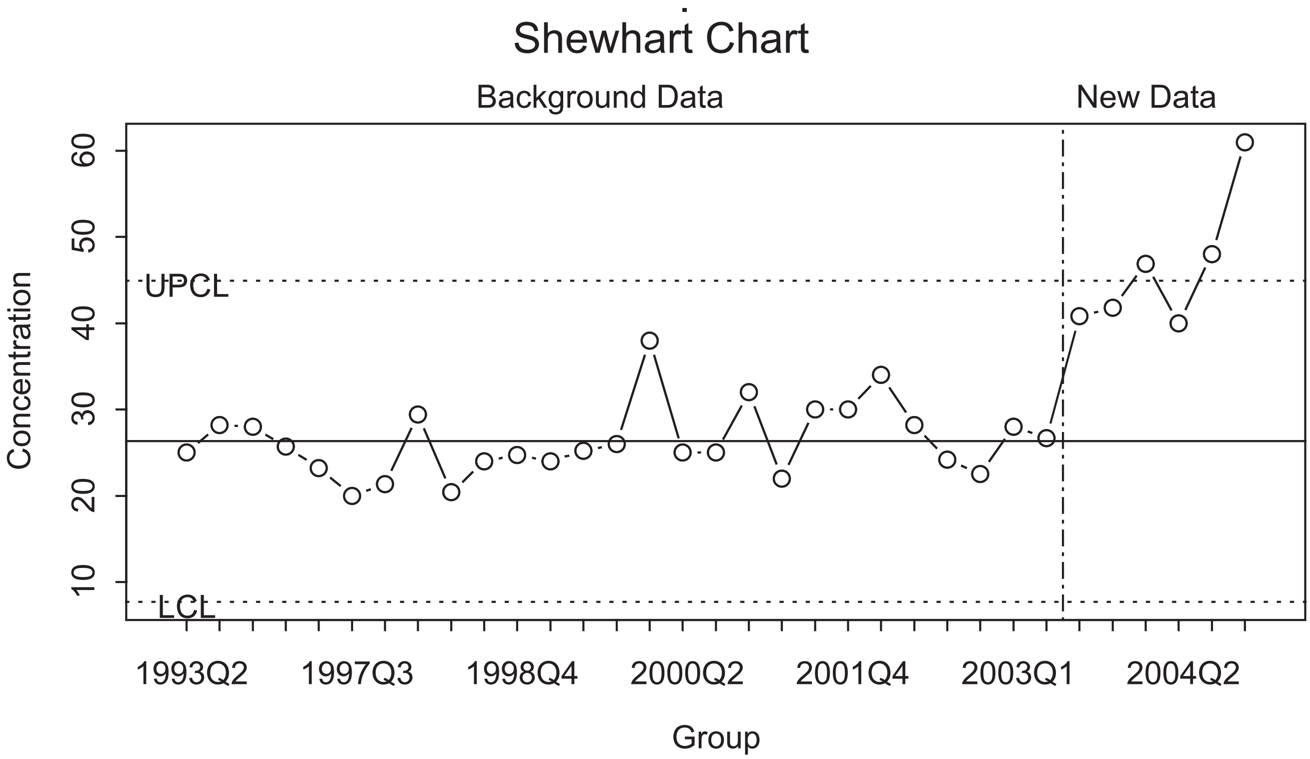
JM o:\Olin\Statistical Analysis\GW-87D SC.ai



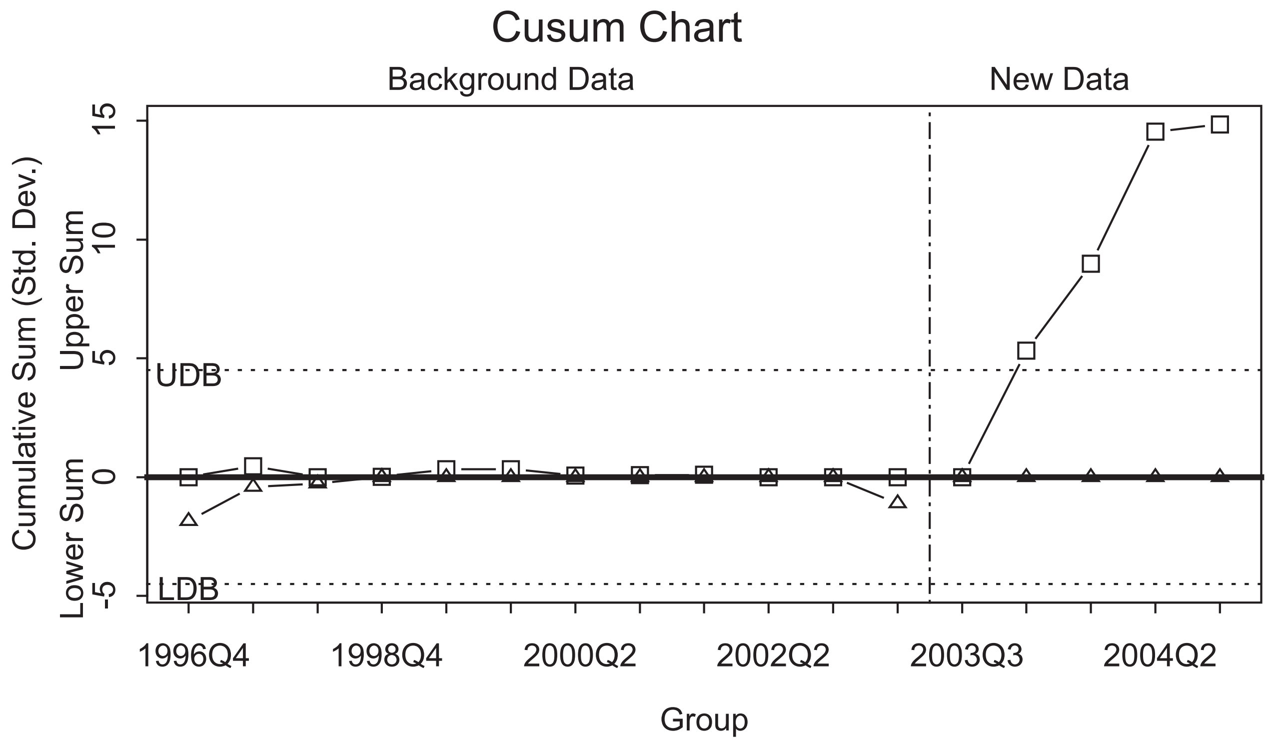


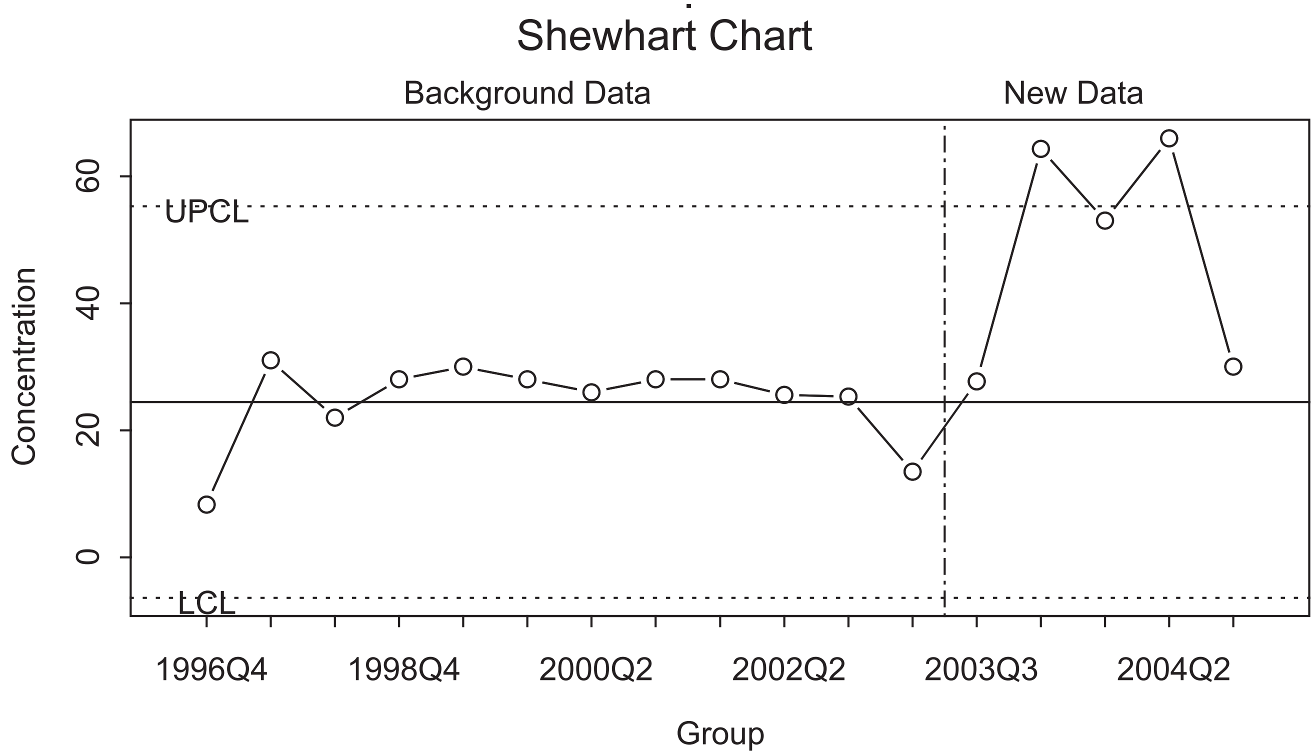
GEOMEGA 8/4/05 C03302C Olin-Wilmington	Control charts for GW-103D sodium, dissolved log (mg/L).	**Figure** 16





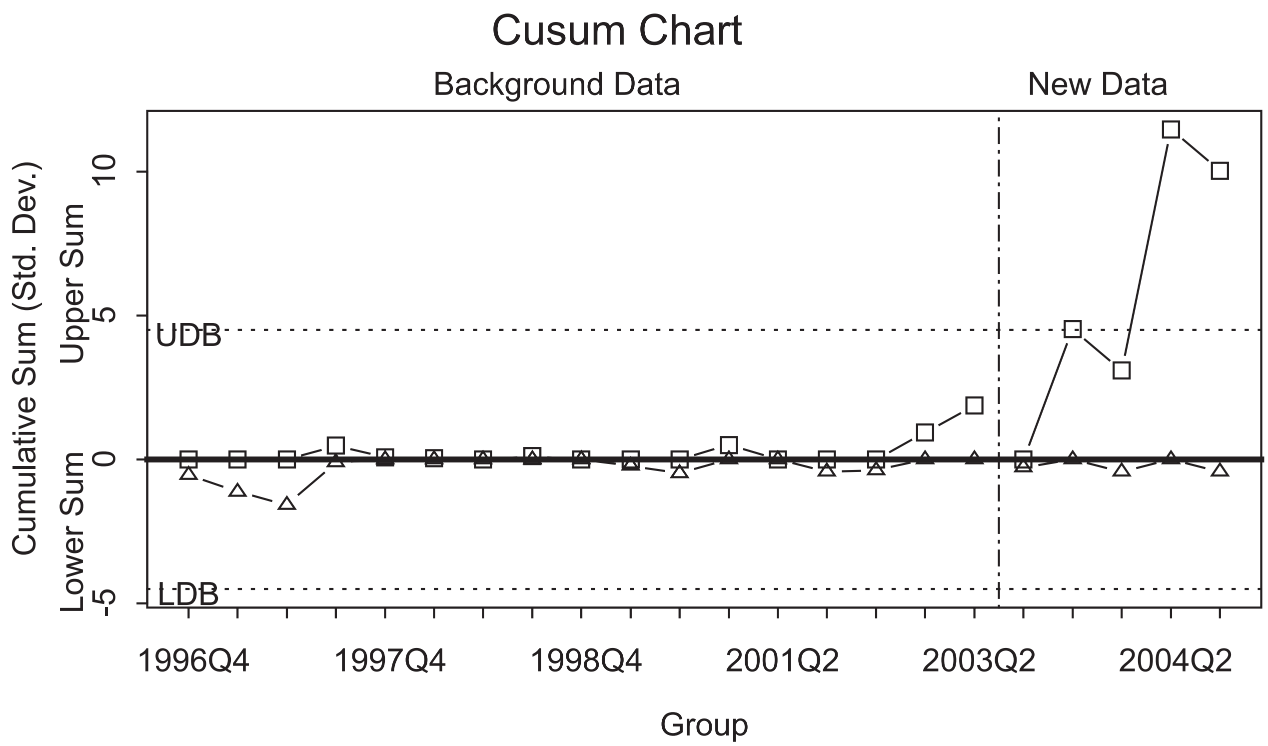
GEOMEGA 8/4/05 C03302C Olin-Wilmington	Control charts for GW-73D sulfate as SO_4 log (mg/L).	**Figure** 17

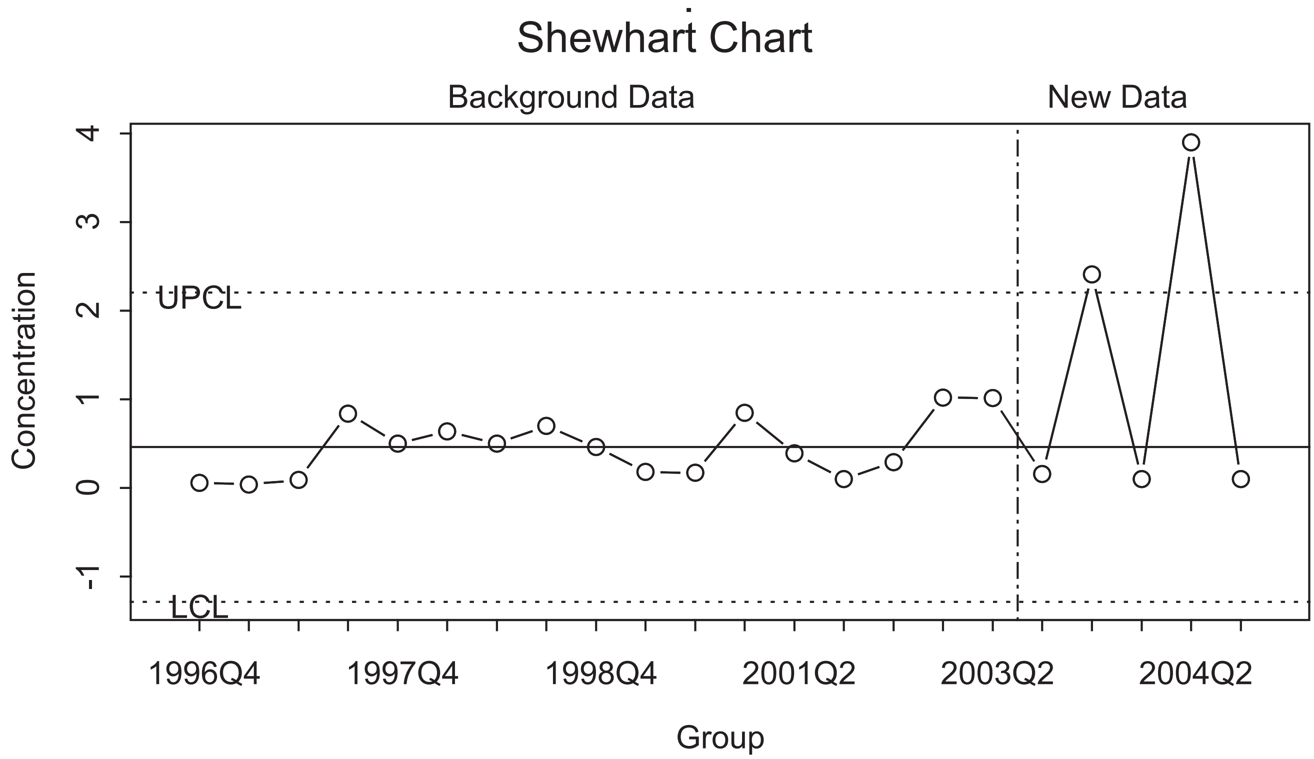




GEOMEGA 8/4/05 C03302C Olin-Wilmington	Control charts for GW-83M nitrogen, ammonia log (mg/L).	**Figure** 18

JM o:\Olin\Statistical Analysis\GW-83M NH3.ai





GEOMEGA

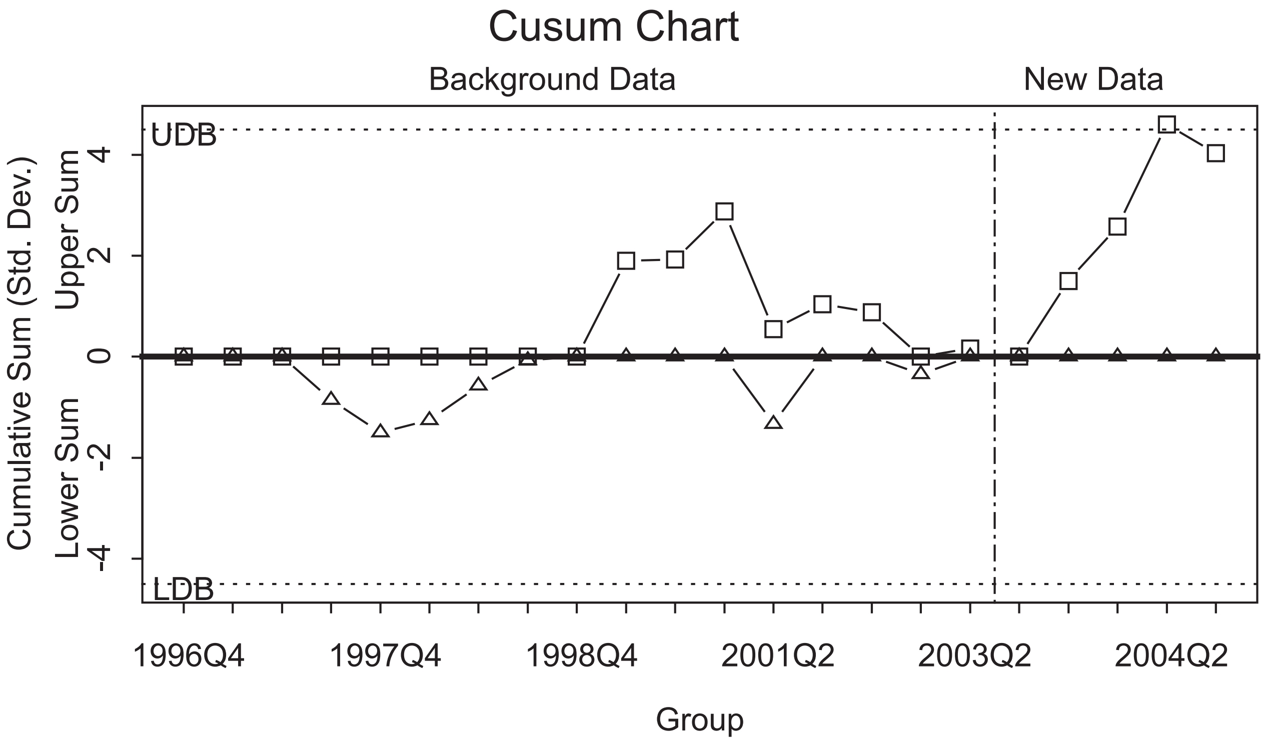
8/4/05

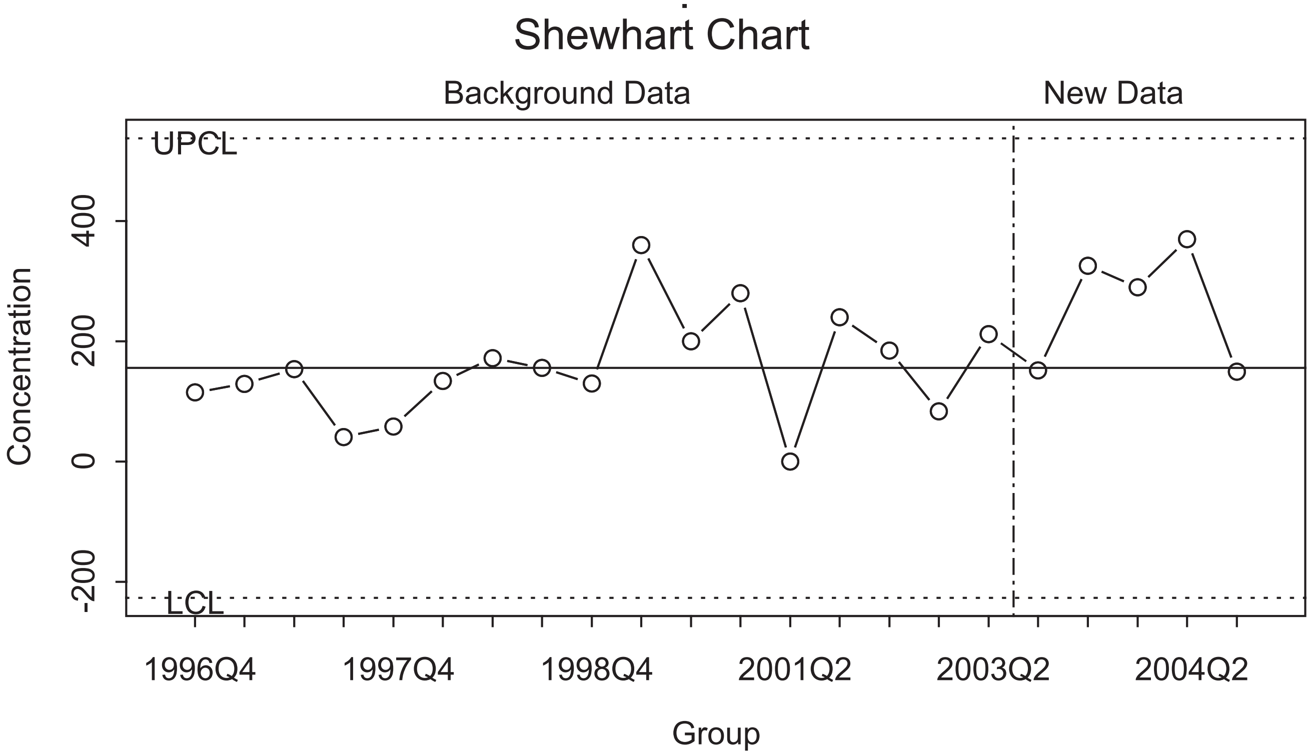
C03302C
Olin-Wilmington

Control charts for GW-84M nitrogen, ammonia log (mg/L).

Figure
19

JM o:\Olin\Statistical Analysis\GW-84M NH3.ai





GEOMEGA

8/4/05

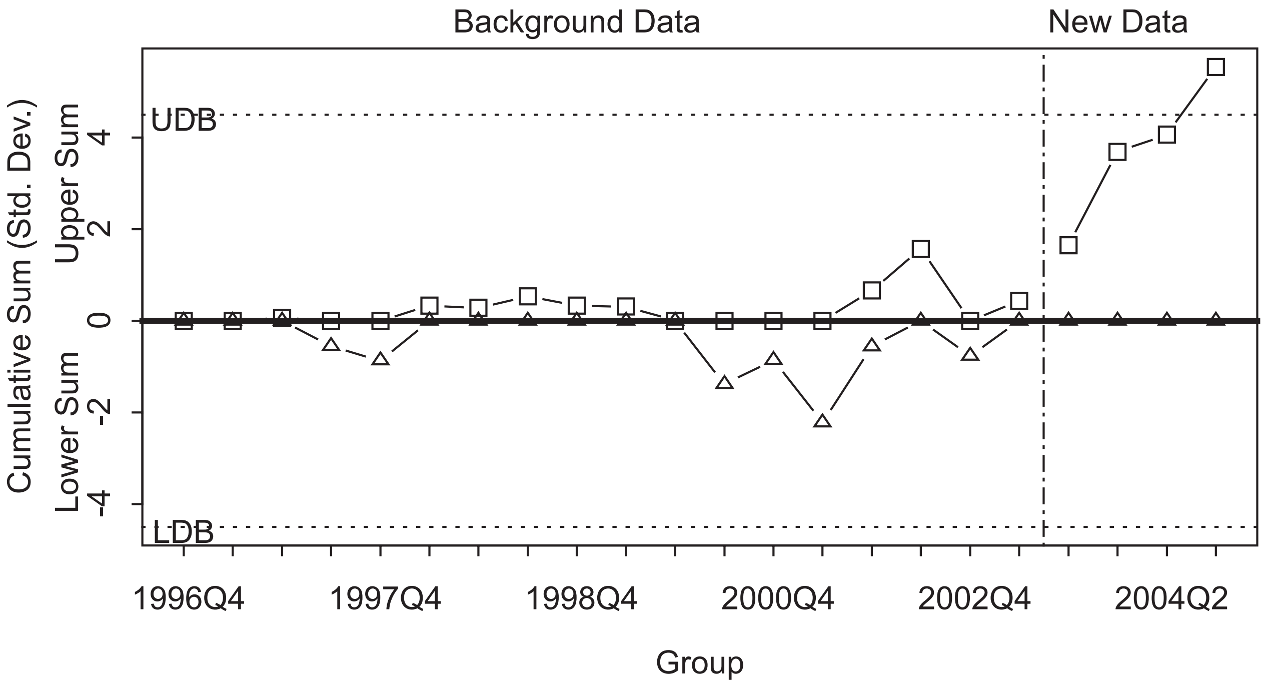
C03302C
Olin-Wilmington

Control charts for GW-84D nitrogen, ammonia log (mg/L).

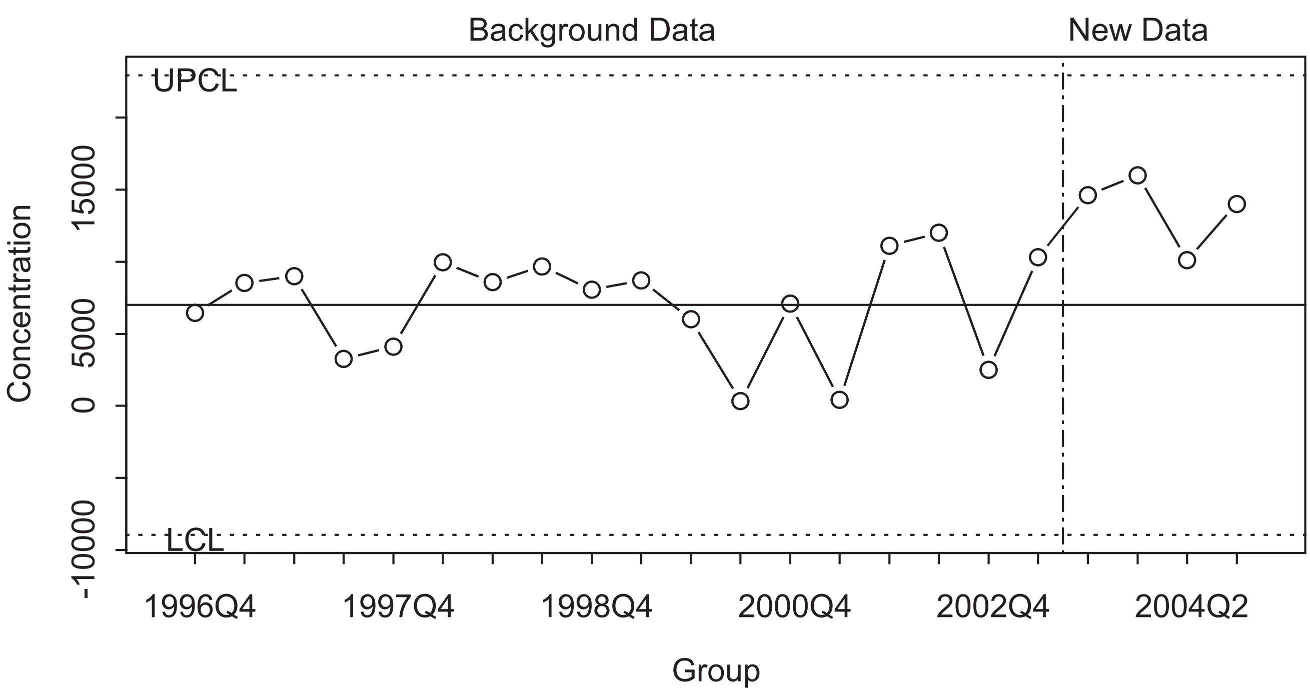
Figure
20

JM o:\Olin\Statistical Analysis\GW-84D NH3.ai

Cusum Chart



Shewhart Chart



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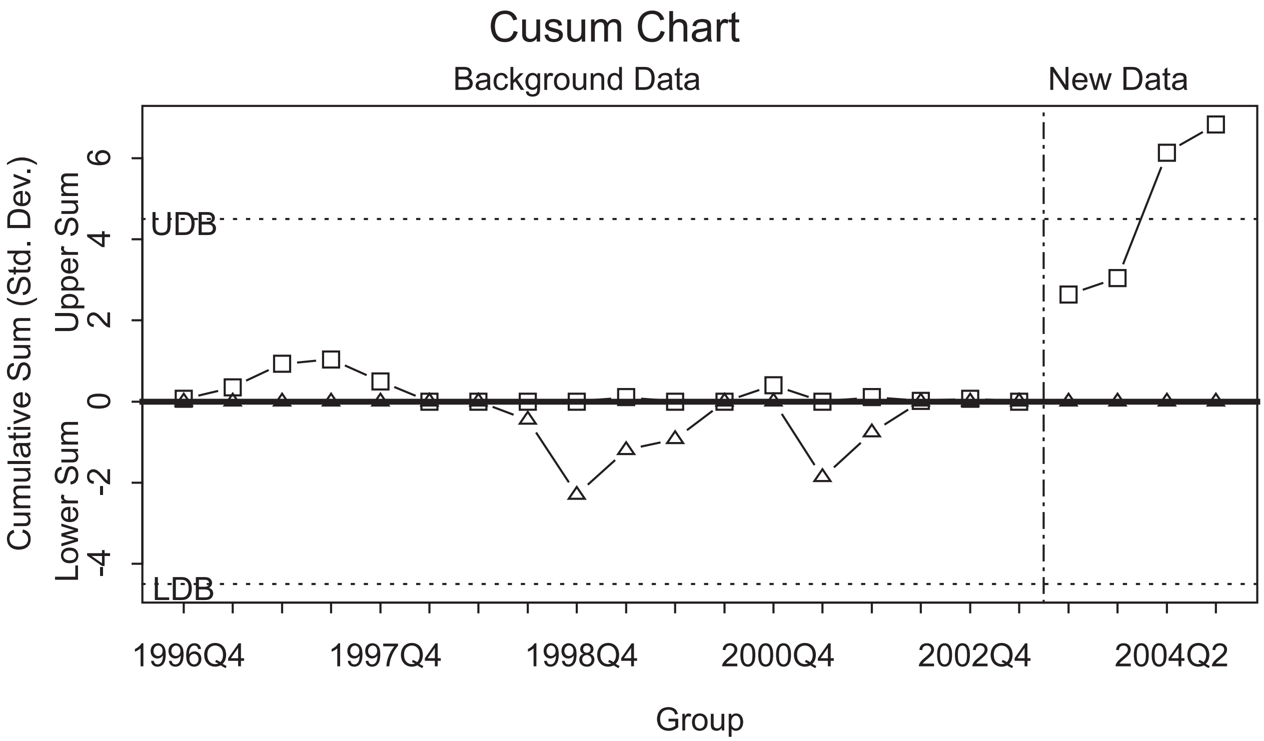
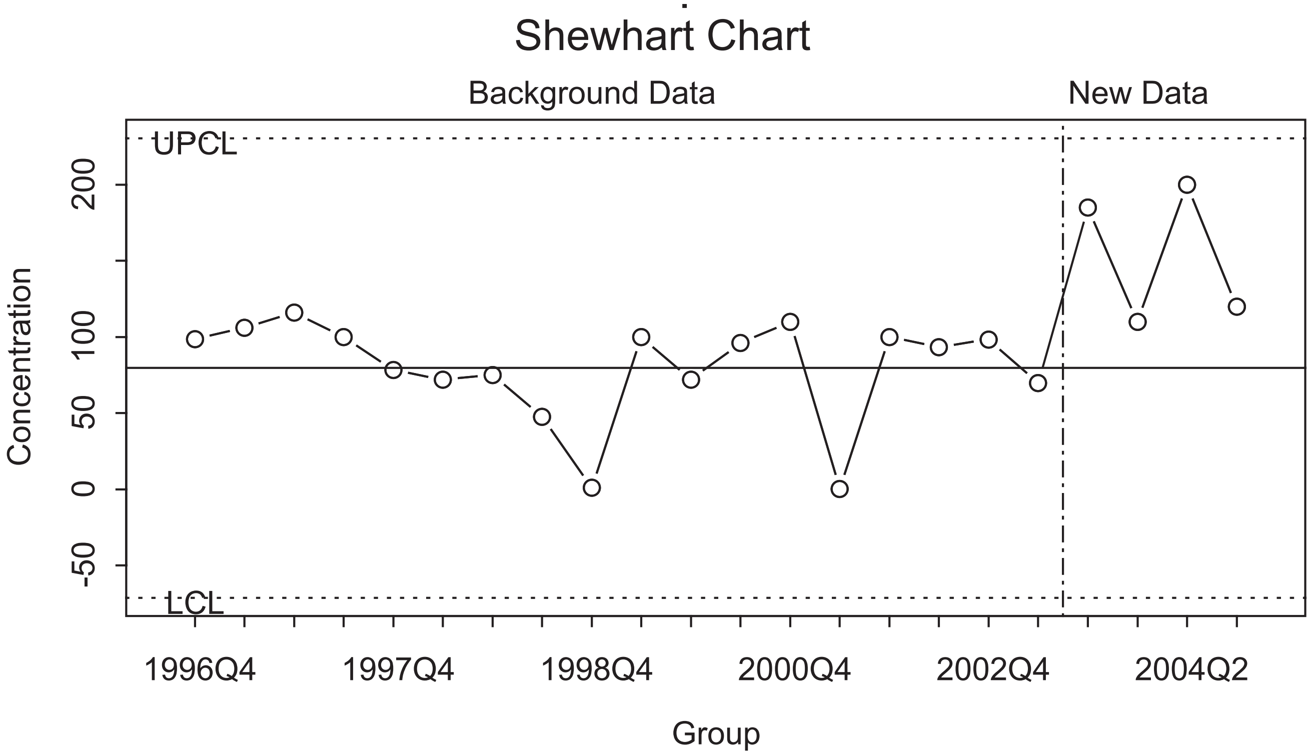
C03302C
Olin-Wilmington

Control charts for GW-84D
specific conductance log (µmhos/cm).

Figure
21

JM o:\Olin\Statistical Analysis\GW-84D SC.ai





GEOMEGA

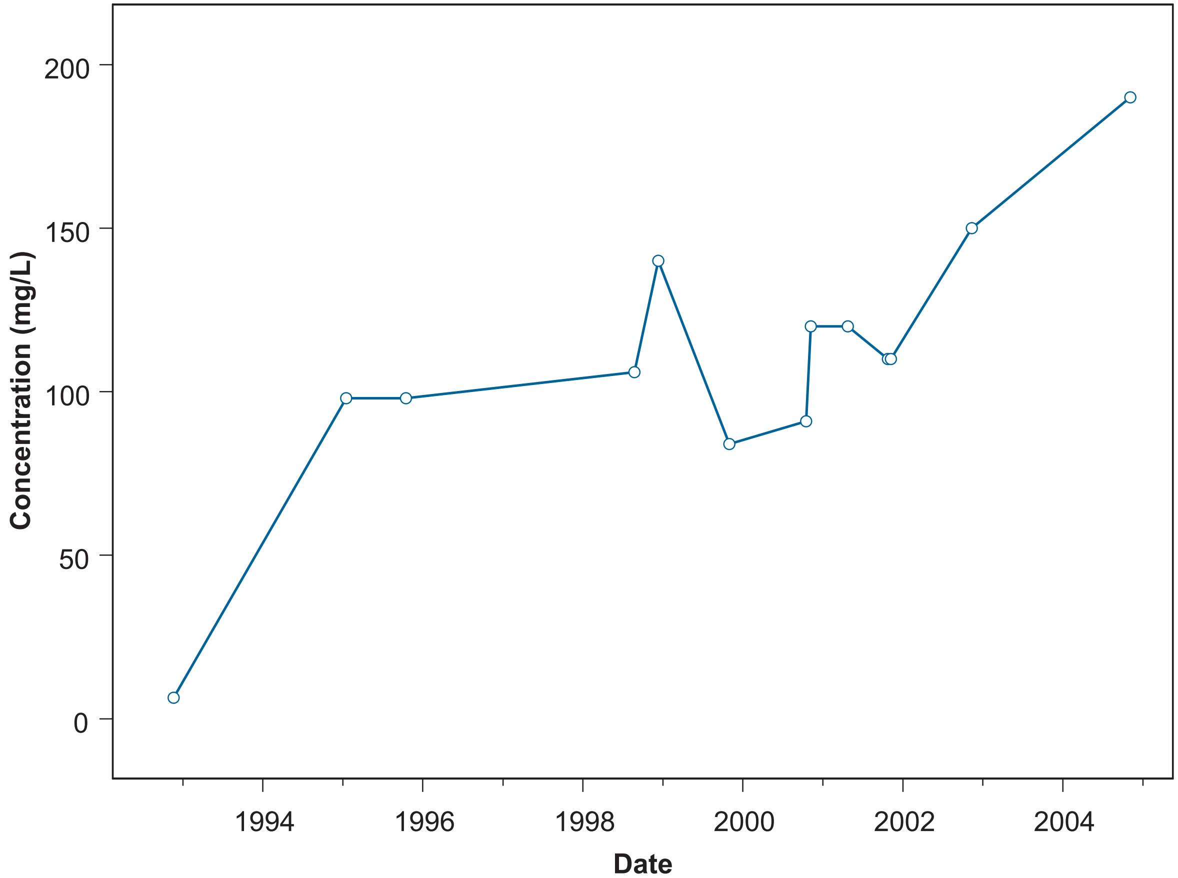
8/4/05

C03302C
Olin-Wilmington

Control charts for GW-85D nitrogen, ammonia log (mg/L).

Figure
22

JM o:\Olin\Statistical Analysis\GW-85D NH3.ai



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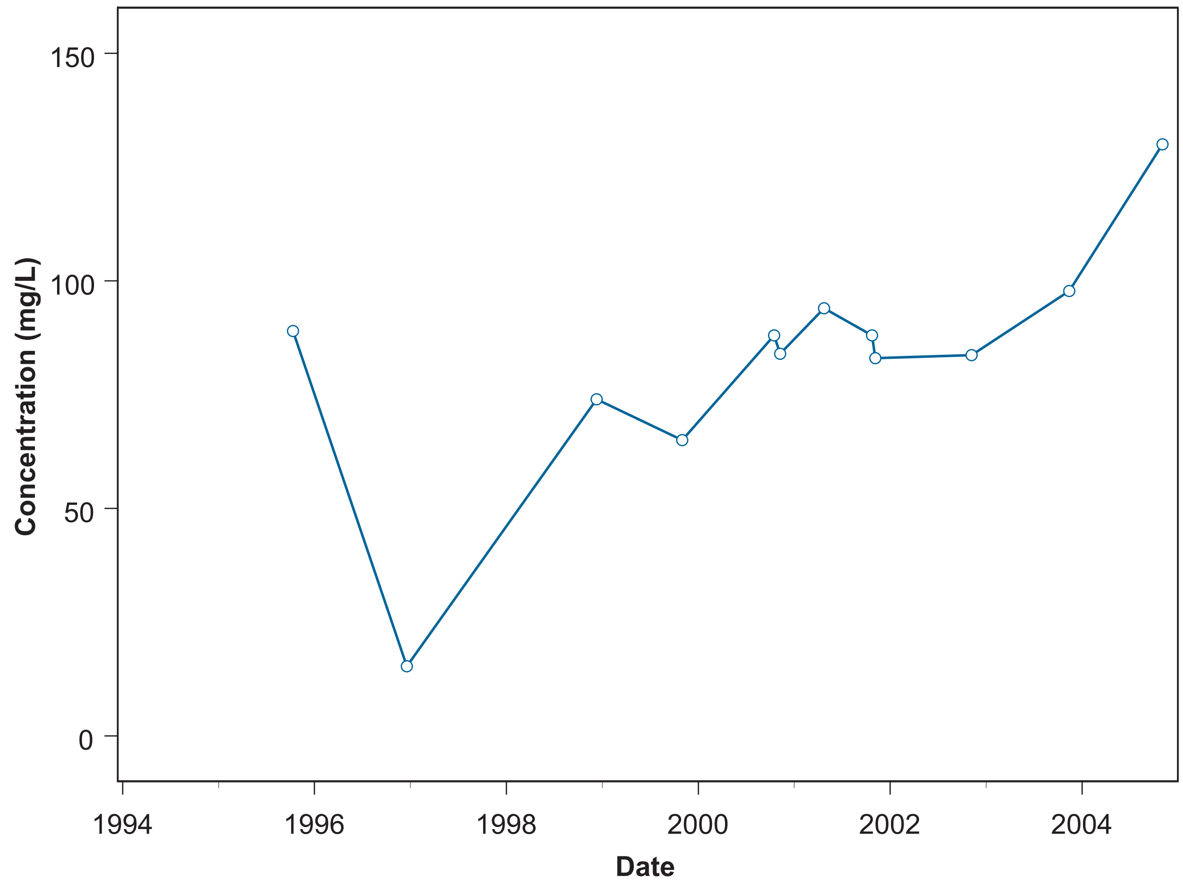
C03302C
Olin-Wilmington

Ammonia concentrations observed in GW-62BR.

Figure
23

JM o:\Olin\Statistical Analysis\62BR NH3.ai



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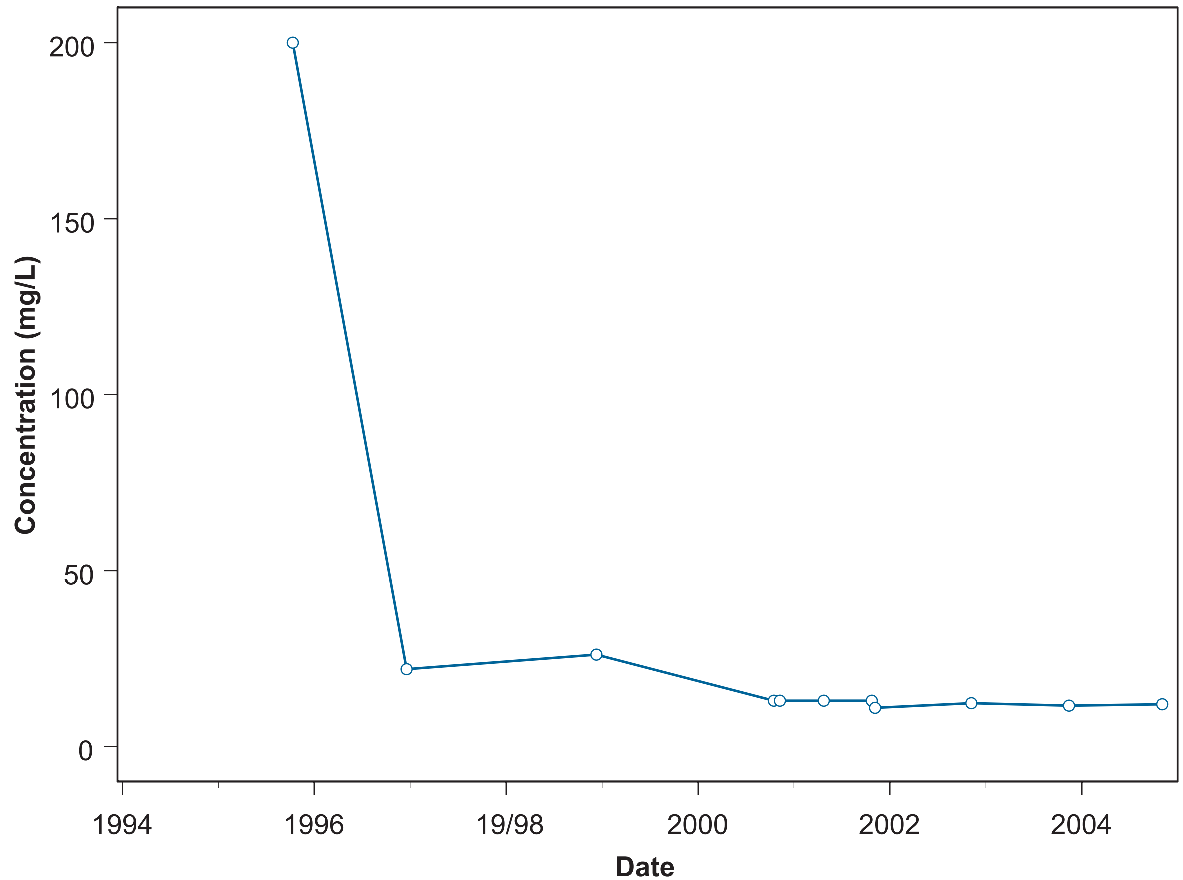
C03302C
Olin-Wilmington

Sodium concentrations observed in GW-65BR.

Figure
24

JM o:\Olin\Statistical Analysis\65BR Na.ai



GEOMEGA

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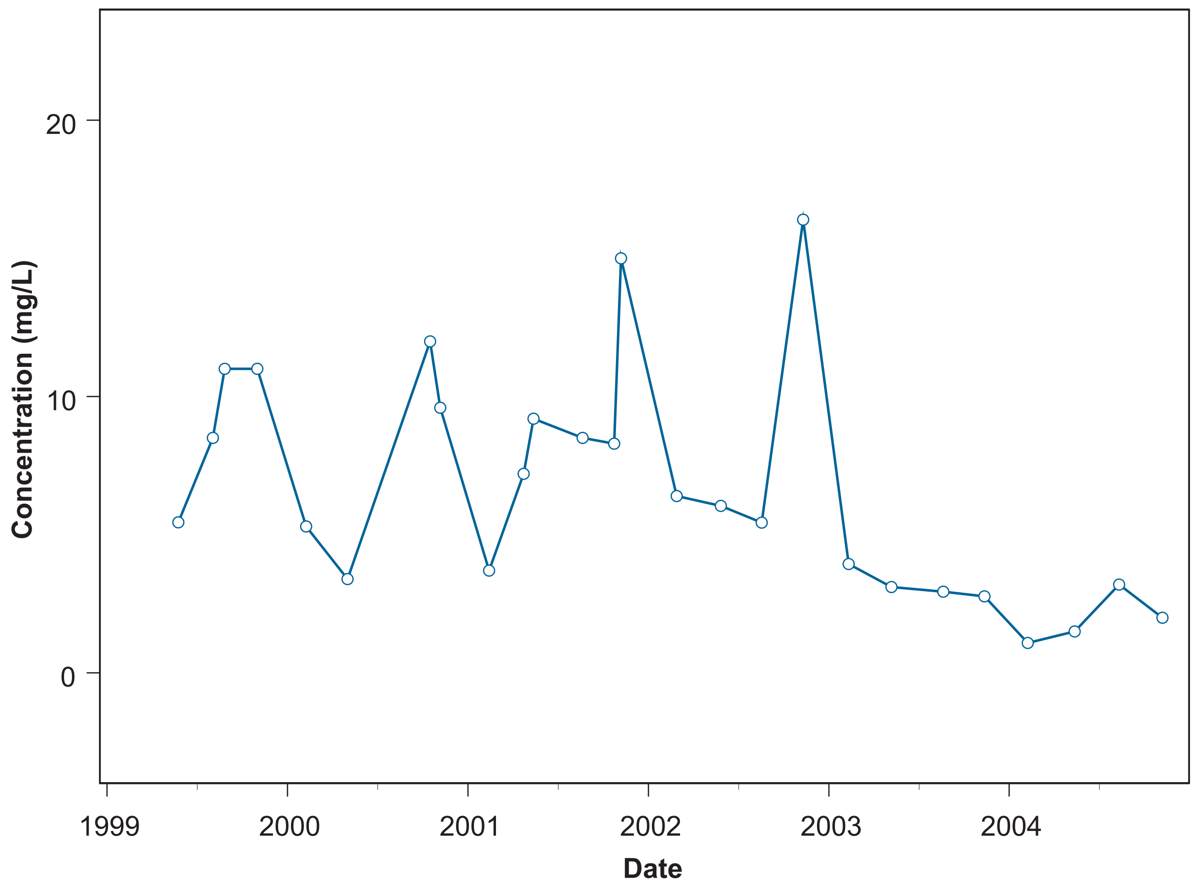
C03302C
Olin-Wilmington

Sulfate concentrations observed in GW-65BR.

Figure
25

JM o:\Olin\Statistical Analysis\65BR SO4.ai



GEOMEGA

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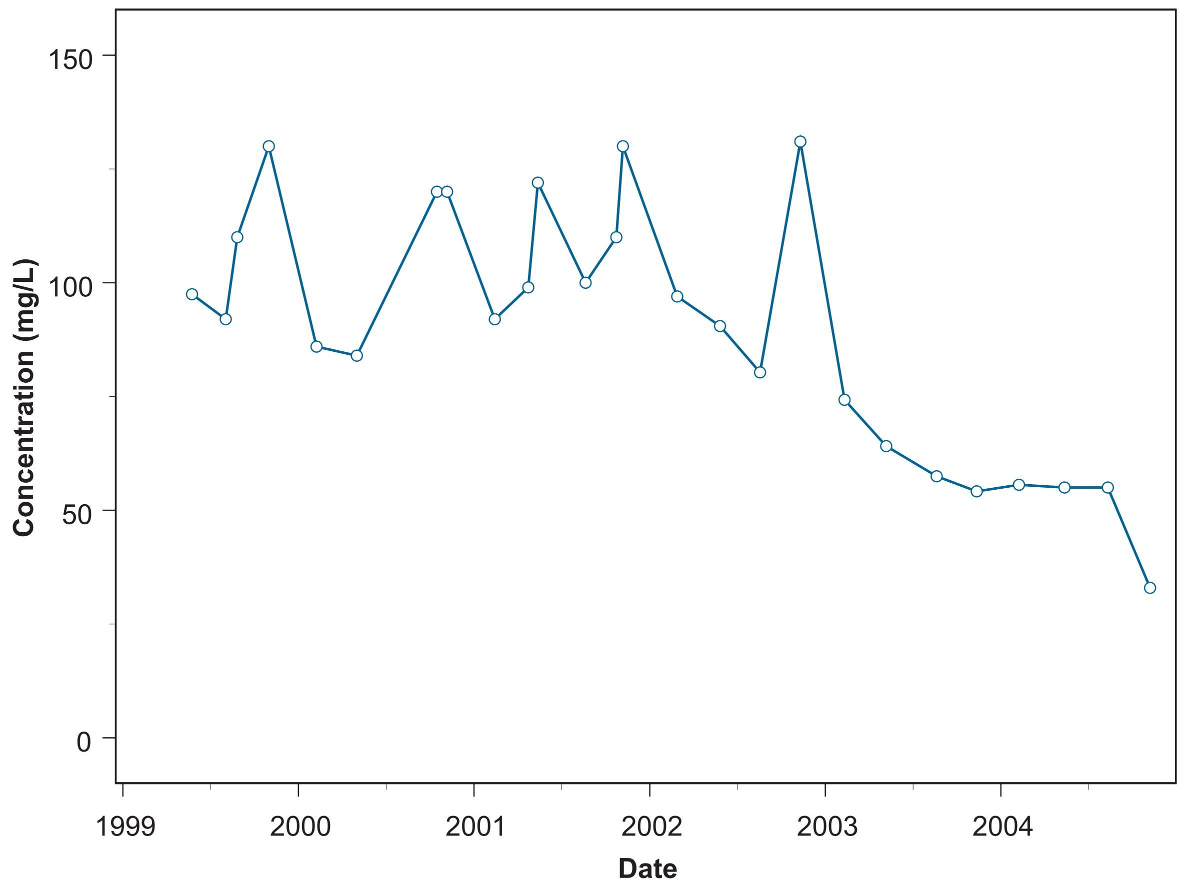
C03302C
Olin-Wilmington

Ammonia concentrations observed in GW-103BR.

Figure
26

JM o:\Olin\Statistical Analysis\103BR NH3.ai



GEOMEGA

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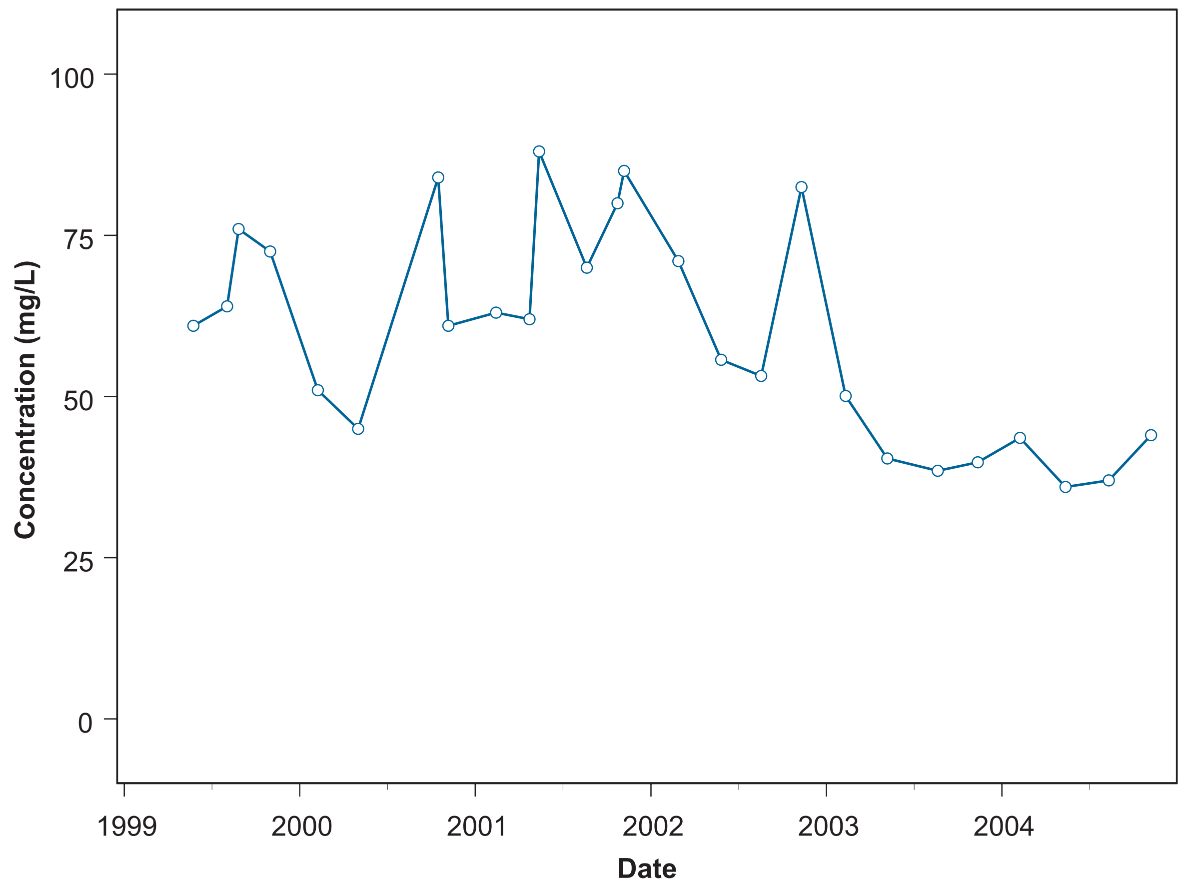
C03302C
Olin-Wilmington

Chloride concentrations observed in GW-103BR.

Figure
27

JM o:\Olin\Statistical Analysis\103BR Cl.ai



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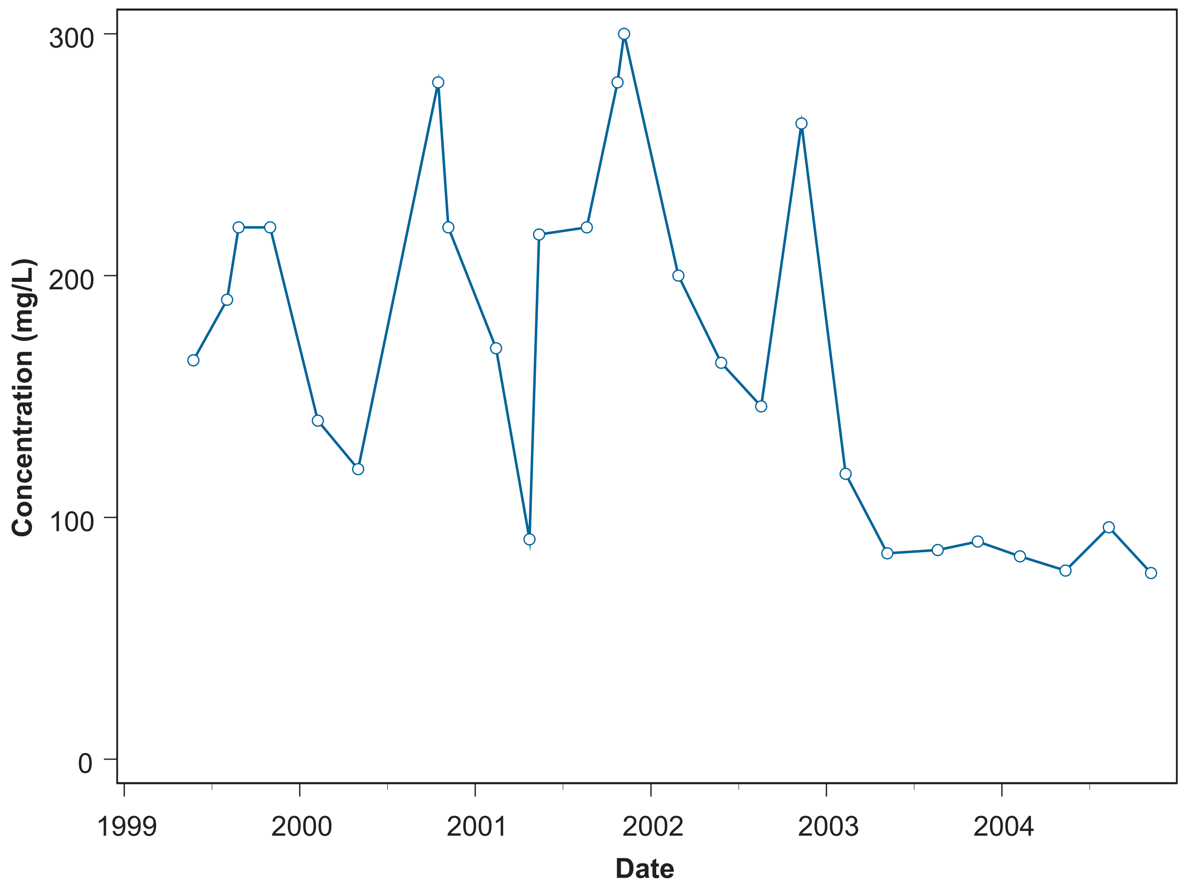
C03302C
Olin-Wilmington

Sodium concentrations observed in GW-103BR.

Figure
28

JM o:\Olin\Statistical Analysis\103BR Na.ai



GEOMEGA

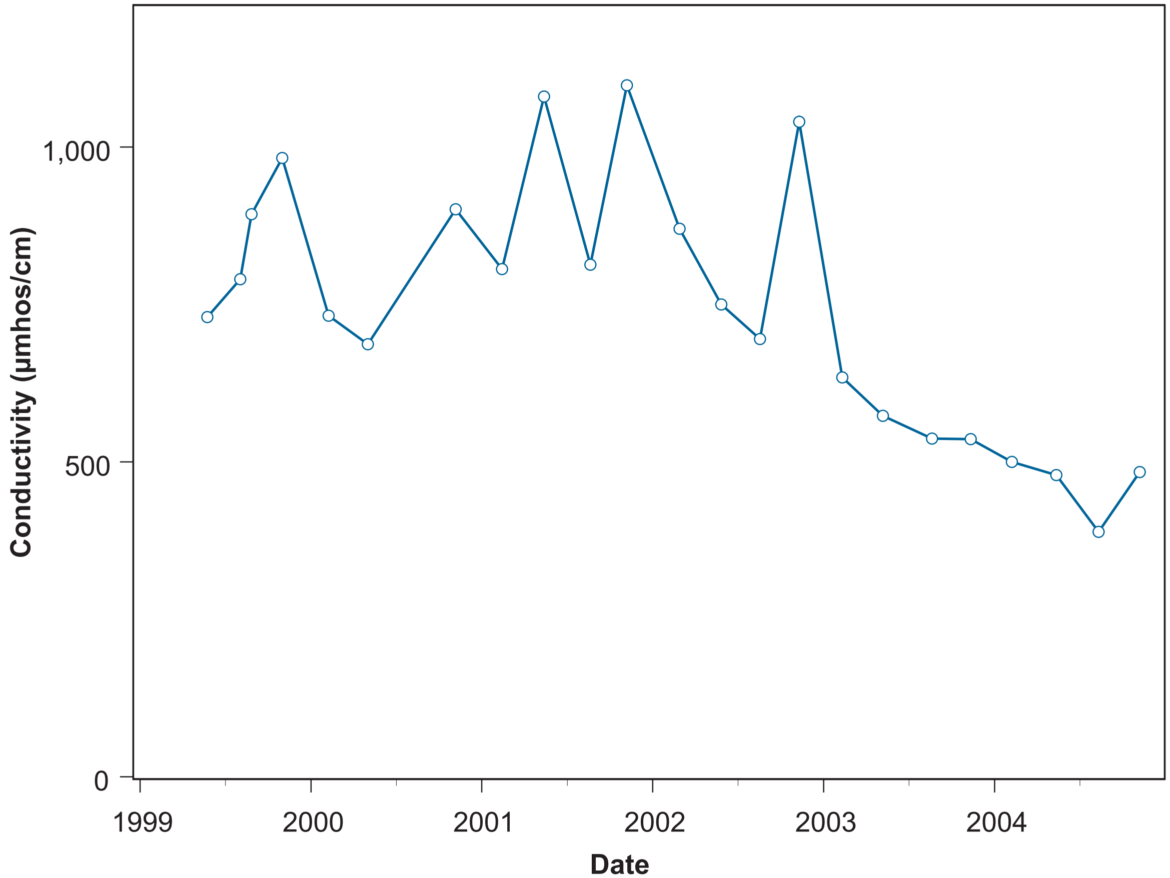
8/4/05

C03302C
Olin-Wilmington

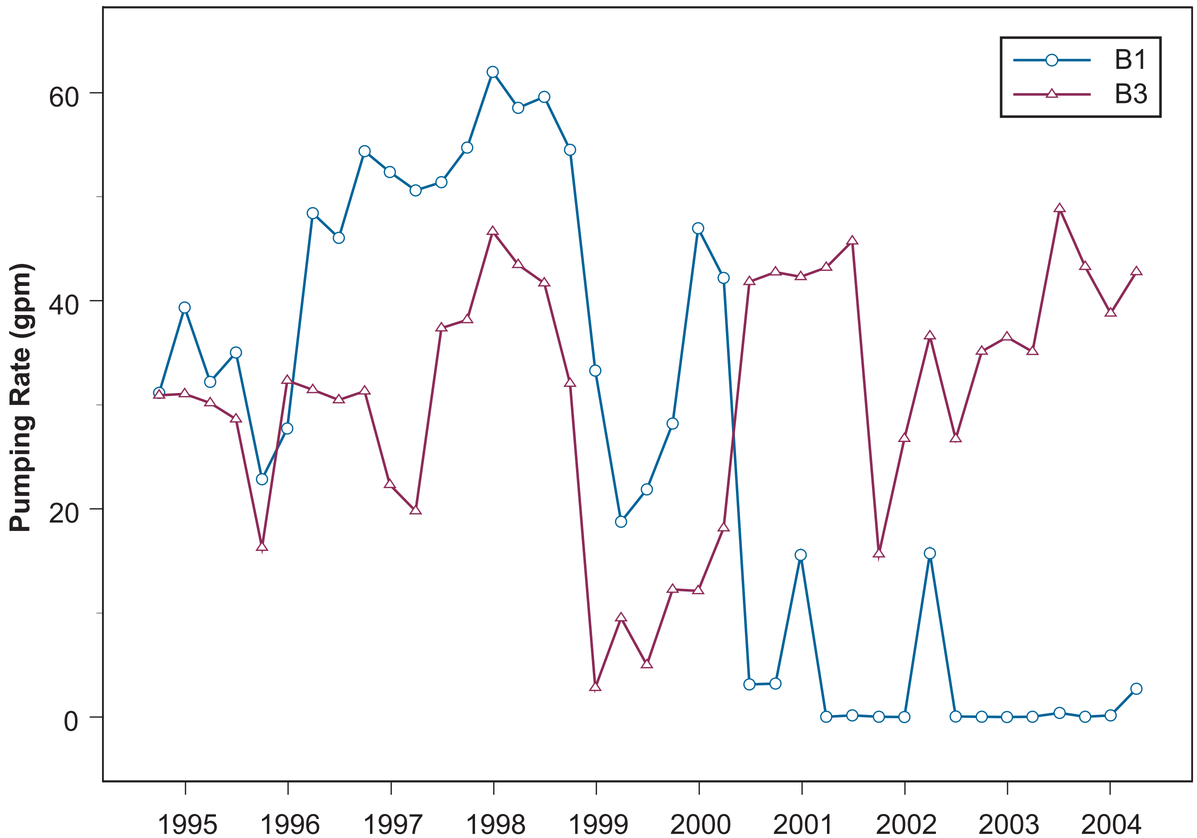
Sulfate concentrations observed in GW-103BR.

Figure
29

JM o:\Olin\Statistical Analysis\103BR SO4.ai



GEOMEGA 8/4/05 C03302C Olin-Wilmington	Specific conductance observed in GW-103BR.	**Figure** 30



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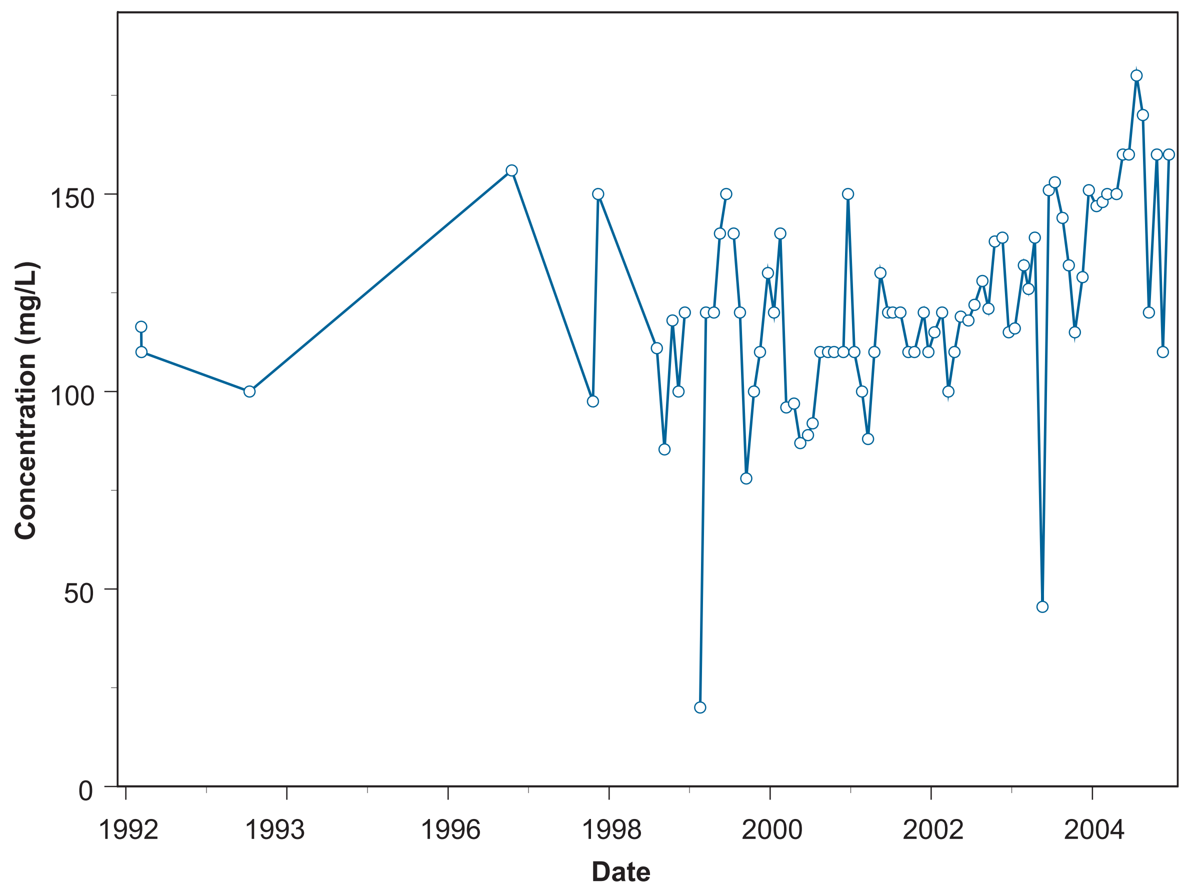
C03302C
Olin-Wilmington

Quarterly pumping rates in the Sanmina wells.

Figure
31

JM o:\Olin\Statistical Analysis\Sanmina Pumping.ai



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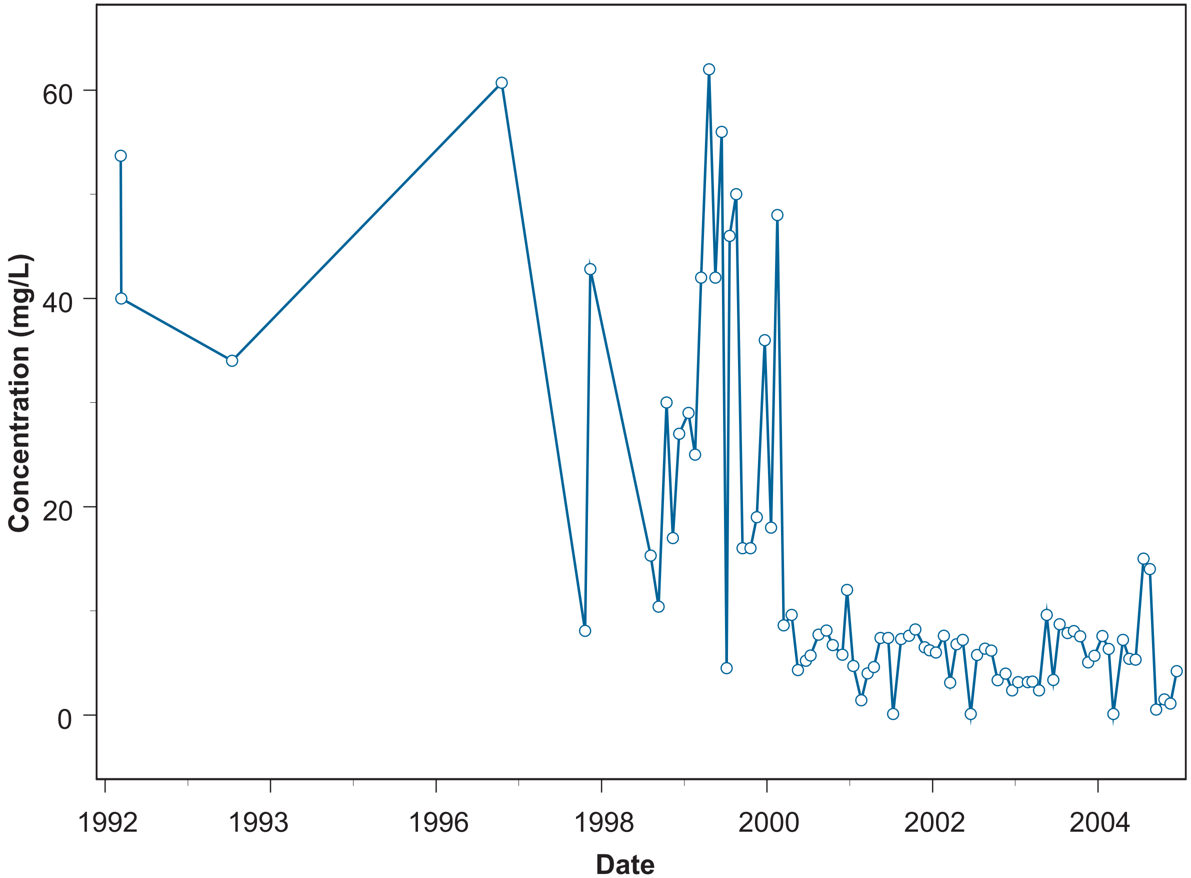
8/4/05

C03302C
Olin-Wilmington

Chloride concentrations observed in Sanmina well B1.

Figure
32

JM o:\Olin\Statistical Analysis\B1 Cl.ai



GEOMEGA

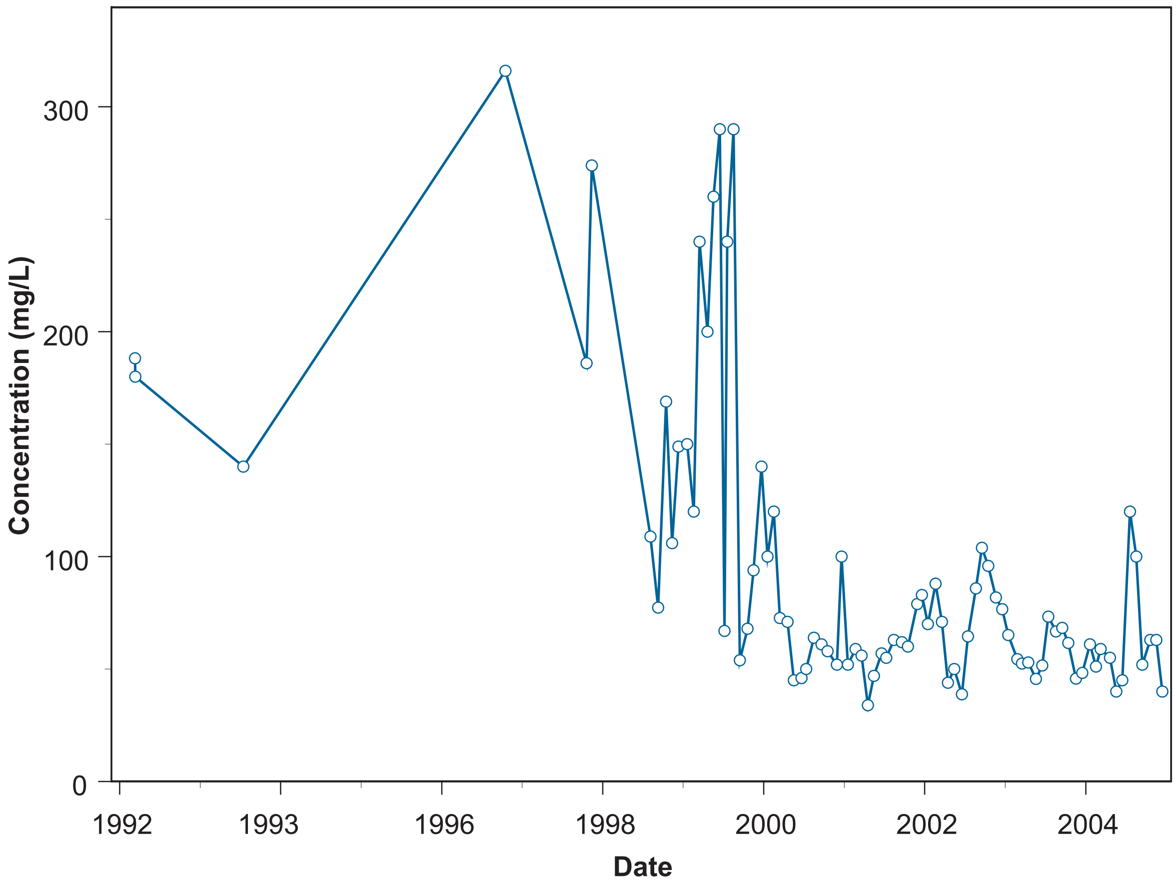
8/4/05

C03302C
Olin-Wilmington

Ammonia concentrations observed in Sanmina well B1.

Figure
33

JM o:\Olin\Statistical Analysis\B1 NH3.ai



GEOMEGA

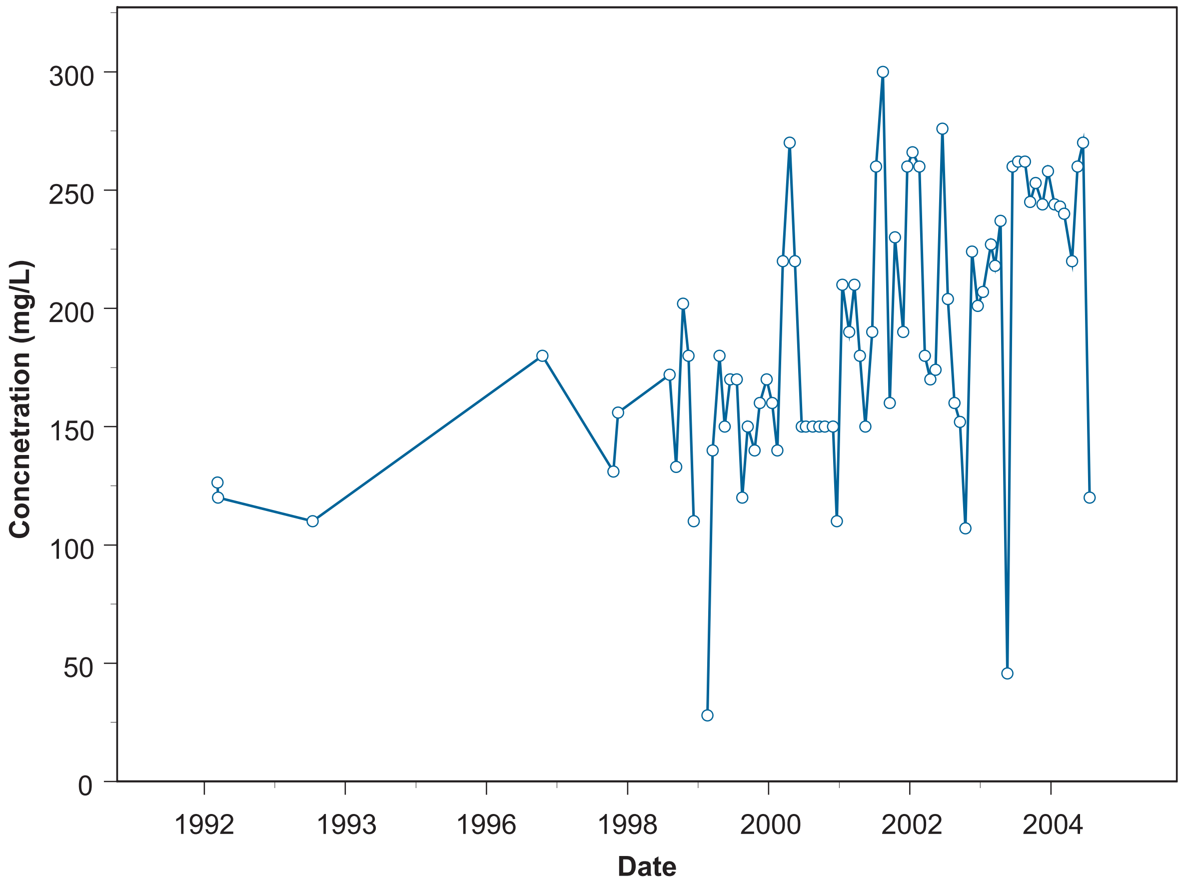
8/4/05

C03302C
Olin-Wilmington

Sulfate concentrations observed in Sanmina well B1.

Figure
34

JM o:\Olin\Statistical Analysis\B1 SO4.ai



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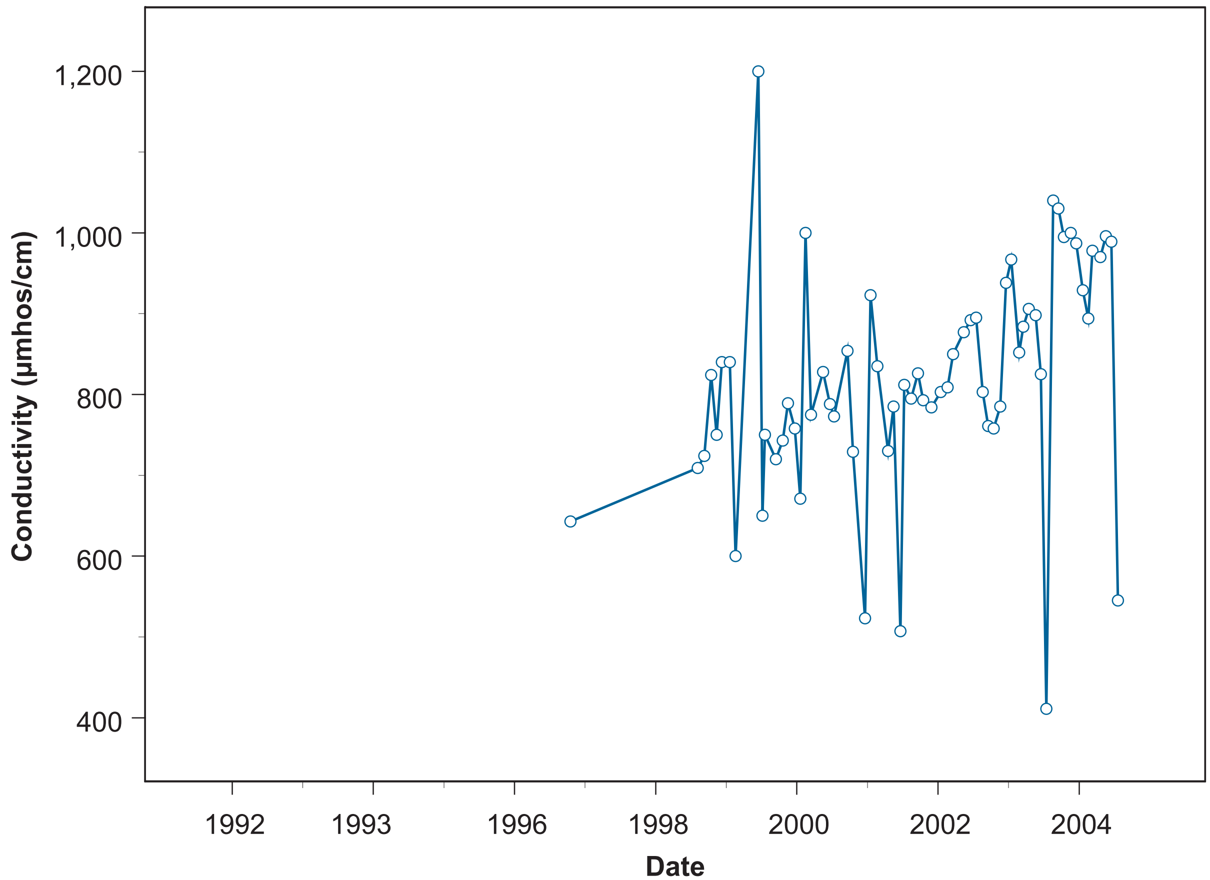
C03302C
Olin-Wilmington

Chloride concentrations observe in Sanmina well B3.

Figure
35

JM o:\Olin\Statistical Analysis\B3 Cl.ai



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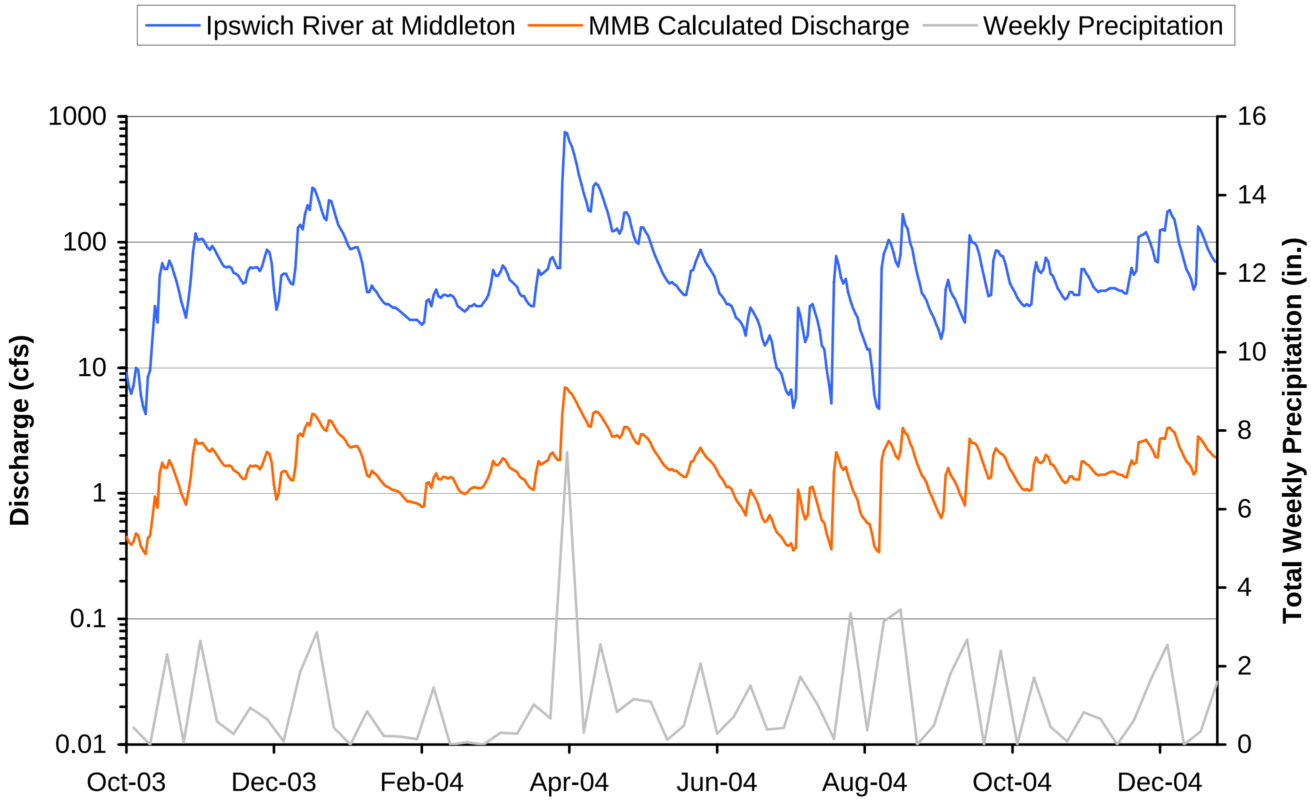
C03302C
Olin-Wilmington

Specific conductance observed in Sanmina well B3.

Figure
36

JM o:\Olin\Statistical Analysis\B3 SC.ai



GEOMEGA

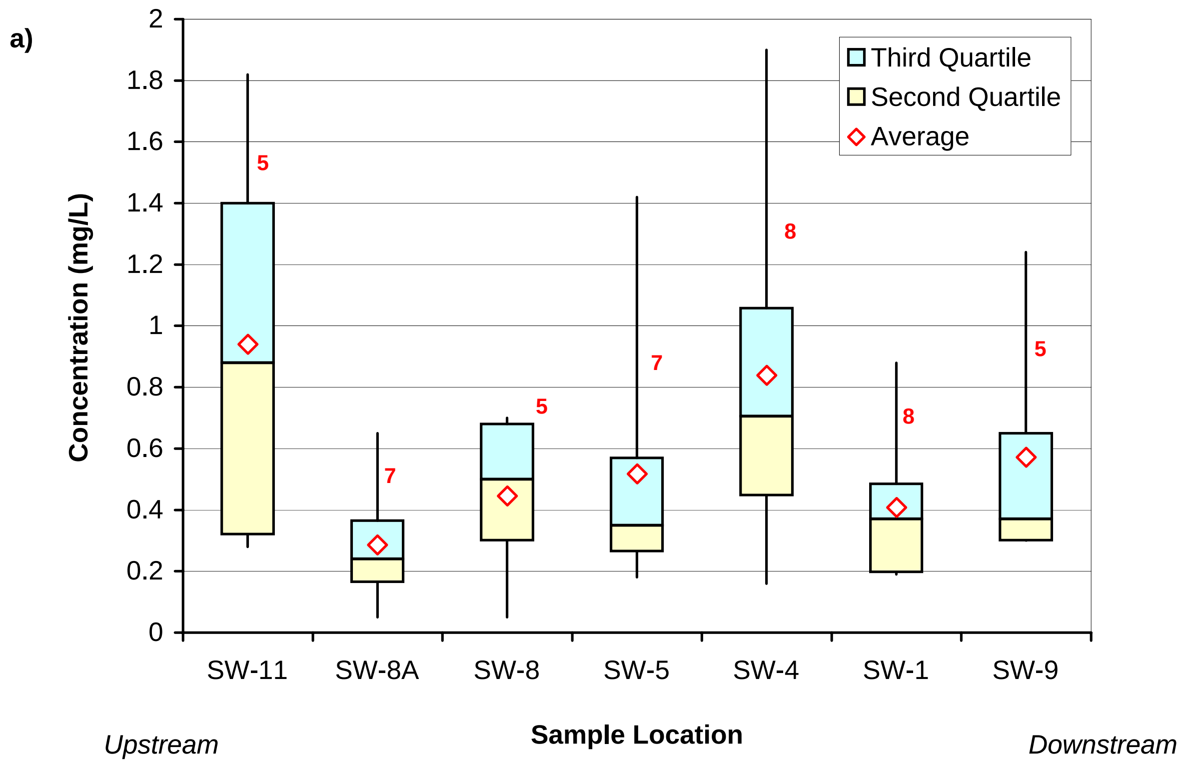
8/4/05

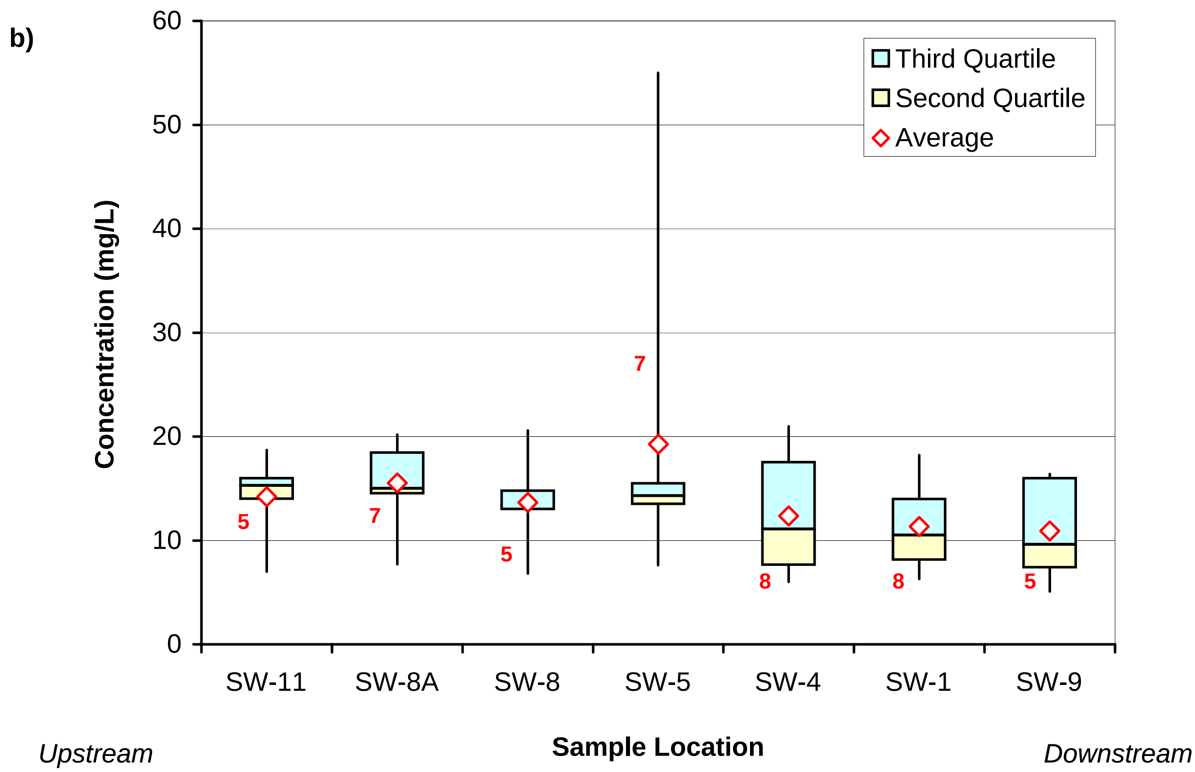
C03302C
Olin-MMB Study Area

Observed Ipswich River daily discharge versus calculated discharge at Maple Meadow Brook (MMB) and recorded weekly precipitation at the Olin facility. (Calculated MMB discharge values based upon Ipswich River discharge regression as explained in the text.)

Figure
37

JM o:\Olin\WBV CD Figures\Ipswich-MMB Q.xls





Note: **5** =Denotes number of data points represented.

GEOMEGA

8/4/05

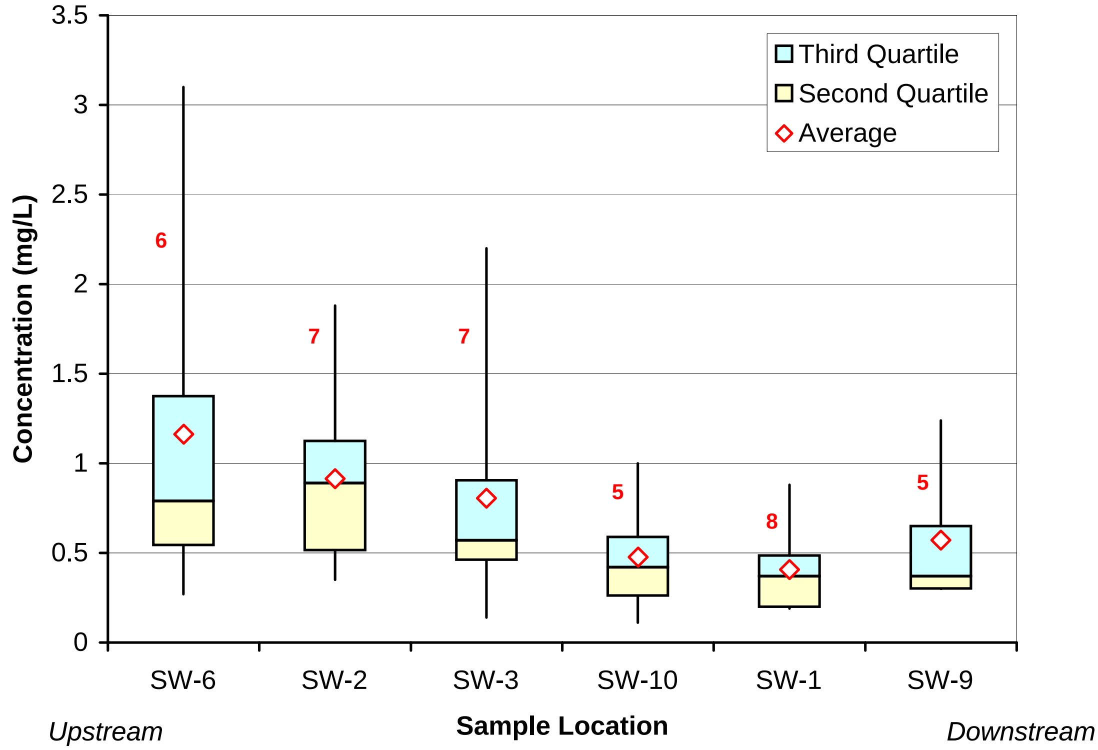
C03302C
Olin-MMB Study

a) Nitrogen, ammonia and b) sulfate concentration distributions in Sawmill Brook surface water.

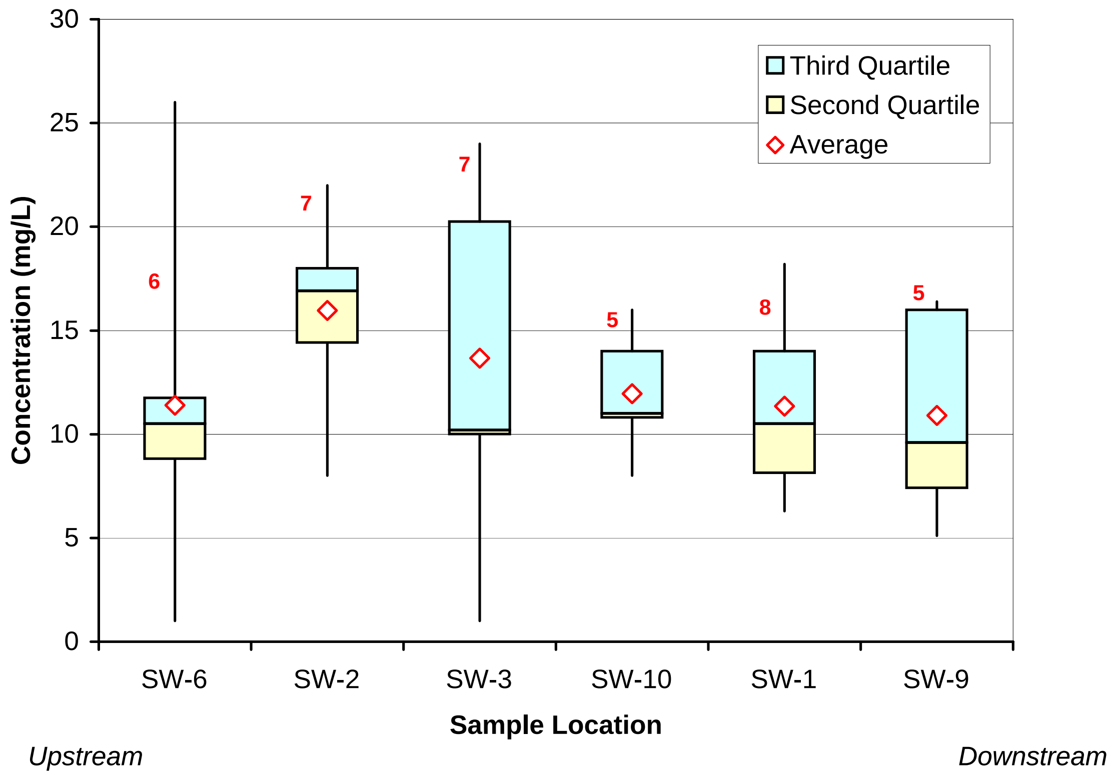
Figure
38

JM o:\Olin\WBV CD Figures\MMB SW results with Box plots 6-05 B (version 2).xls

a)



b)

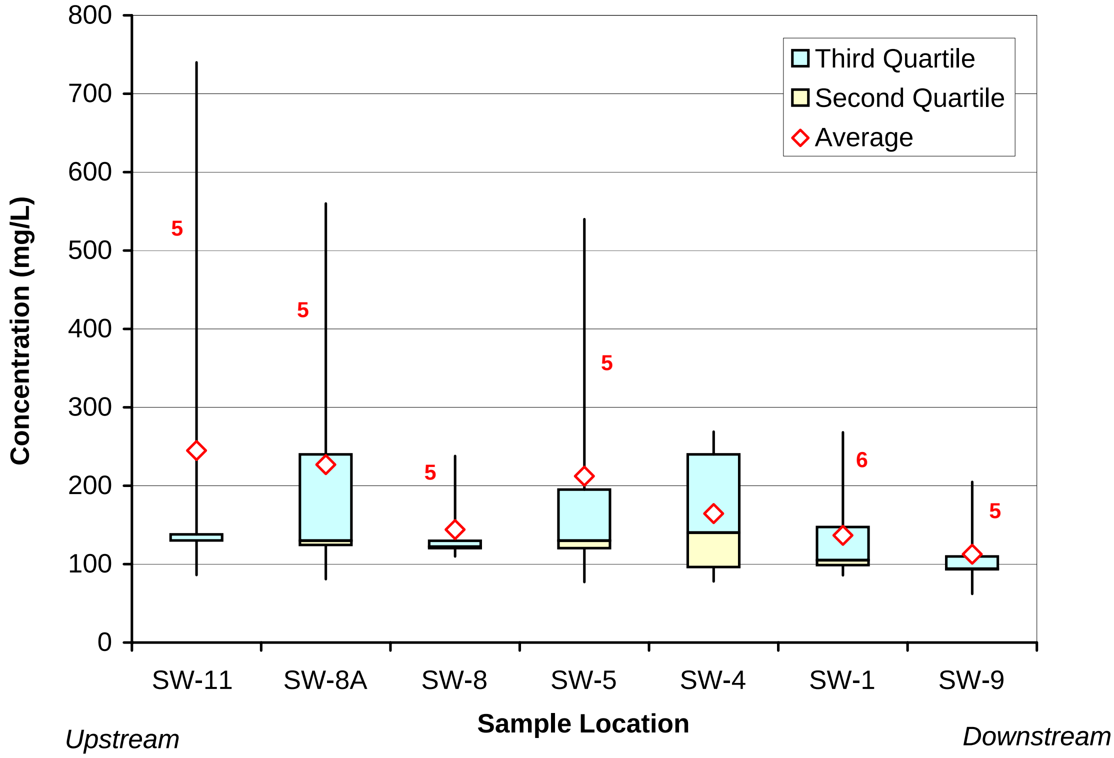


Note: 5 = Denotes number of data points represented.

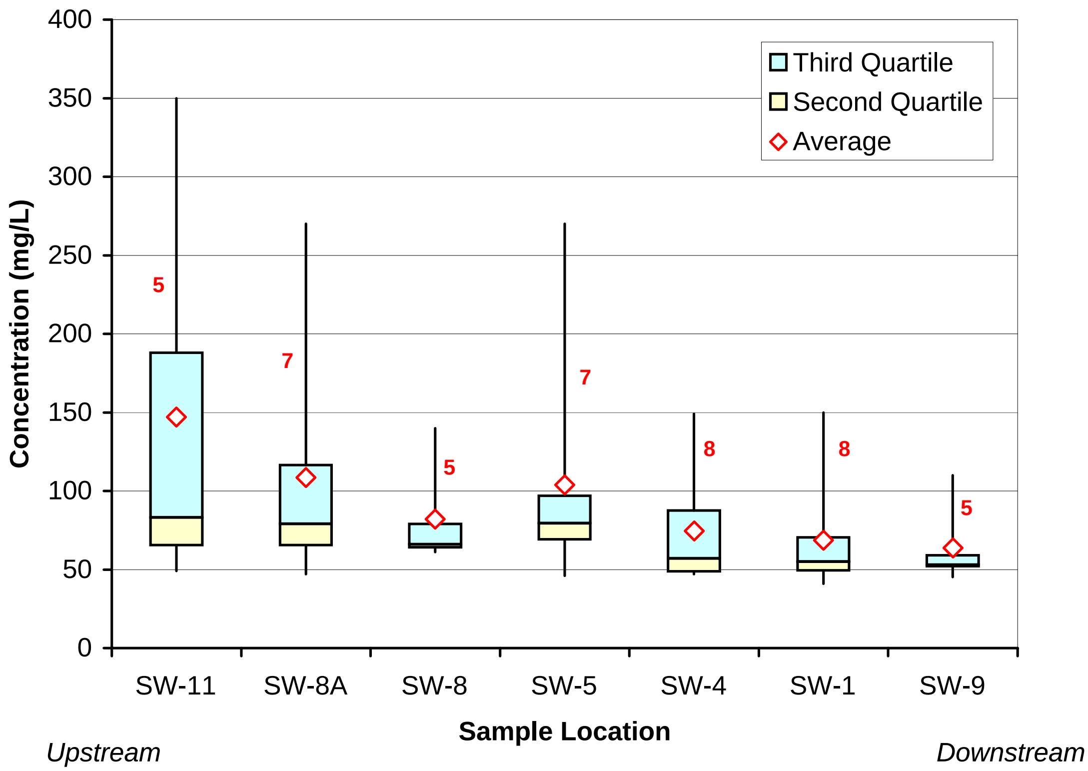
GEOMEGA	a) Nitrogen, ammonia and b) sulfate concentration distributions in Maple Meadow Brook surface water.	**Figure** 39
8/4/05		
C03302C Olin-MMB Study		

JM o:\Olin\WBV CD Figures\MMB SW results with Box plots 6-05 B (version 2).xls

a)



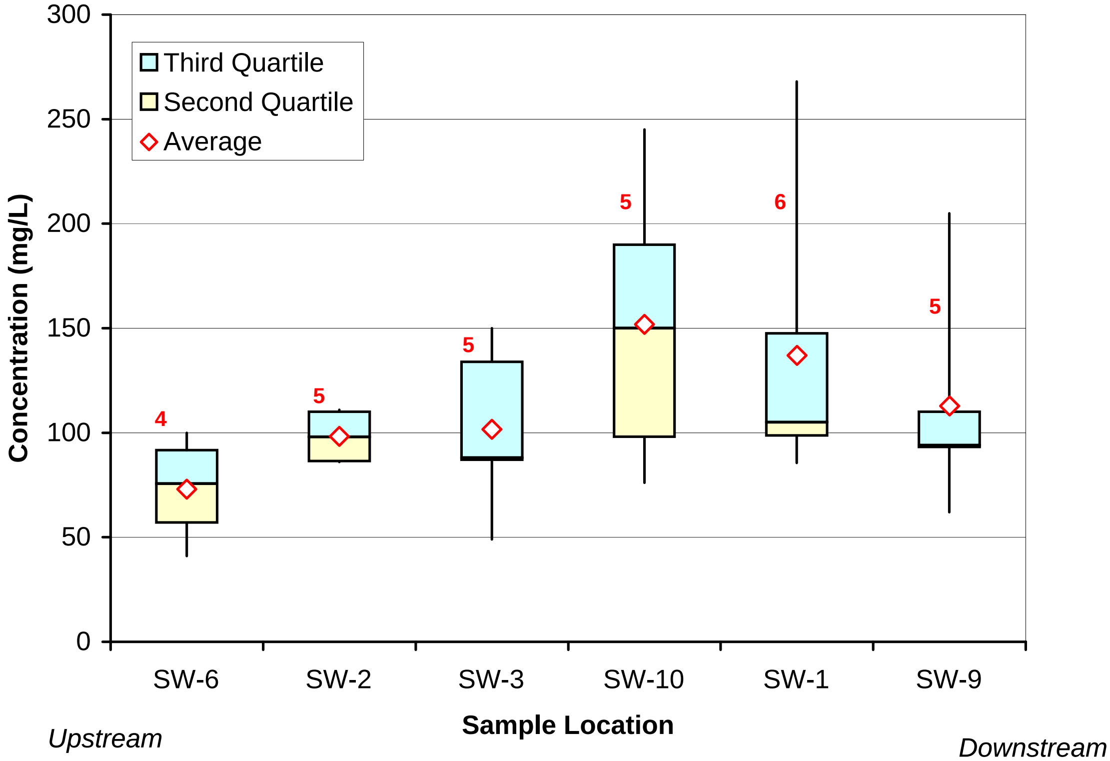
b)



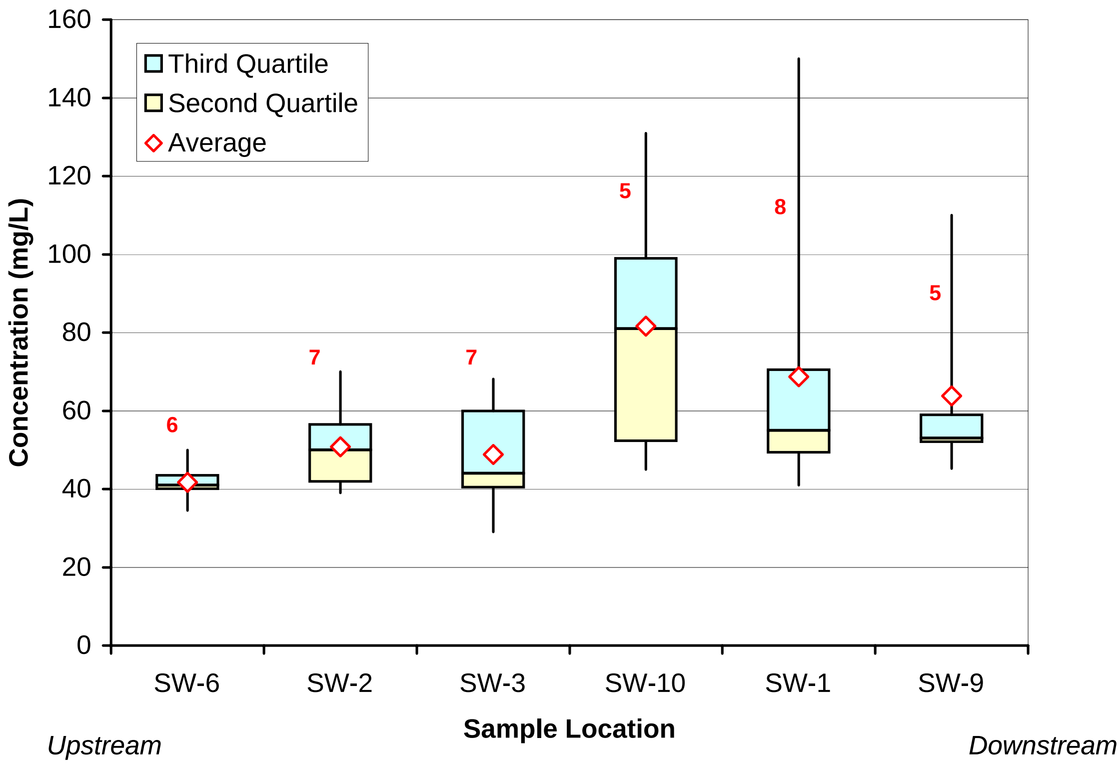
Note: **5** = Denotes number of data points represented.

GEOMEGA	a) Chloride and b) sodium (dissolved) concentration distributions in Sawmill Brook surface water.	**Figure** 40
8/4/05		
C03302C Olin-MMB Study		

a)



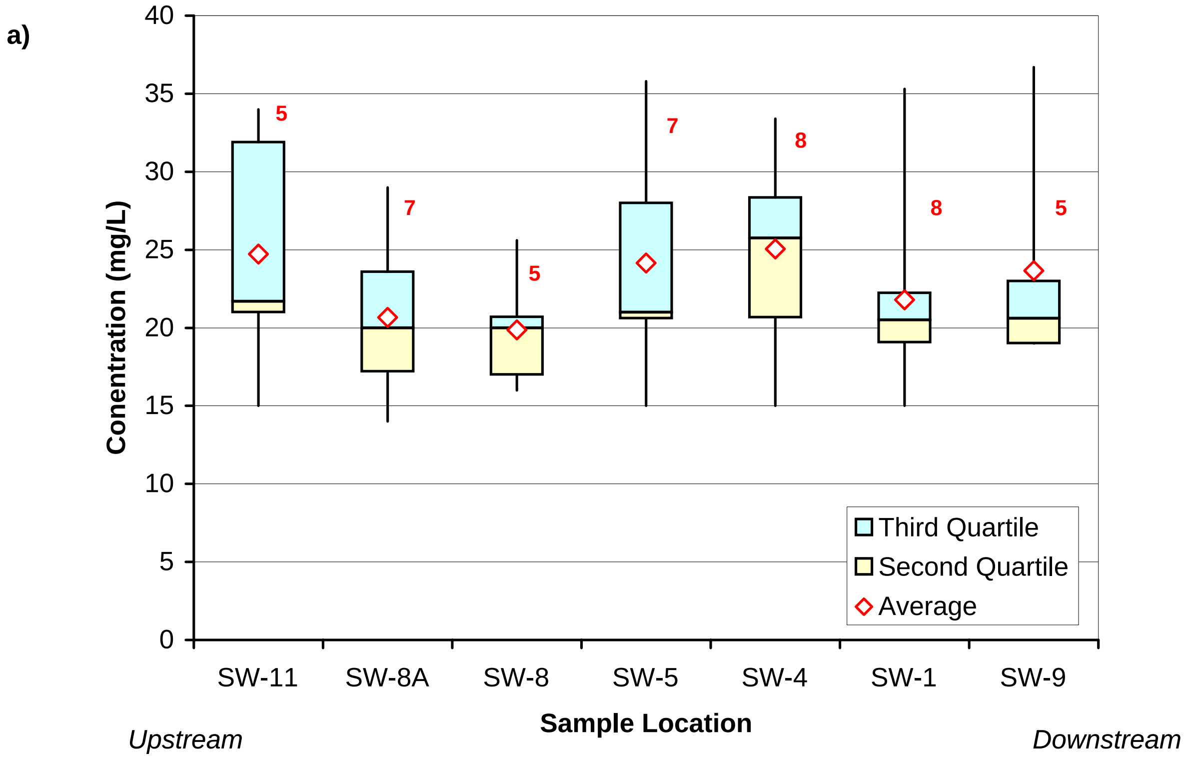
b)



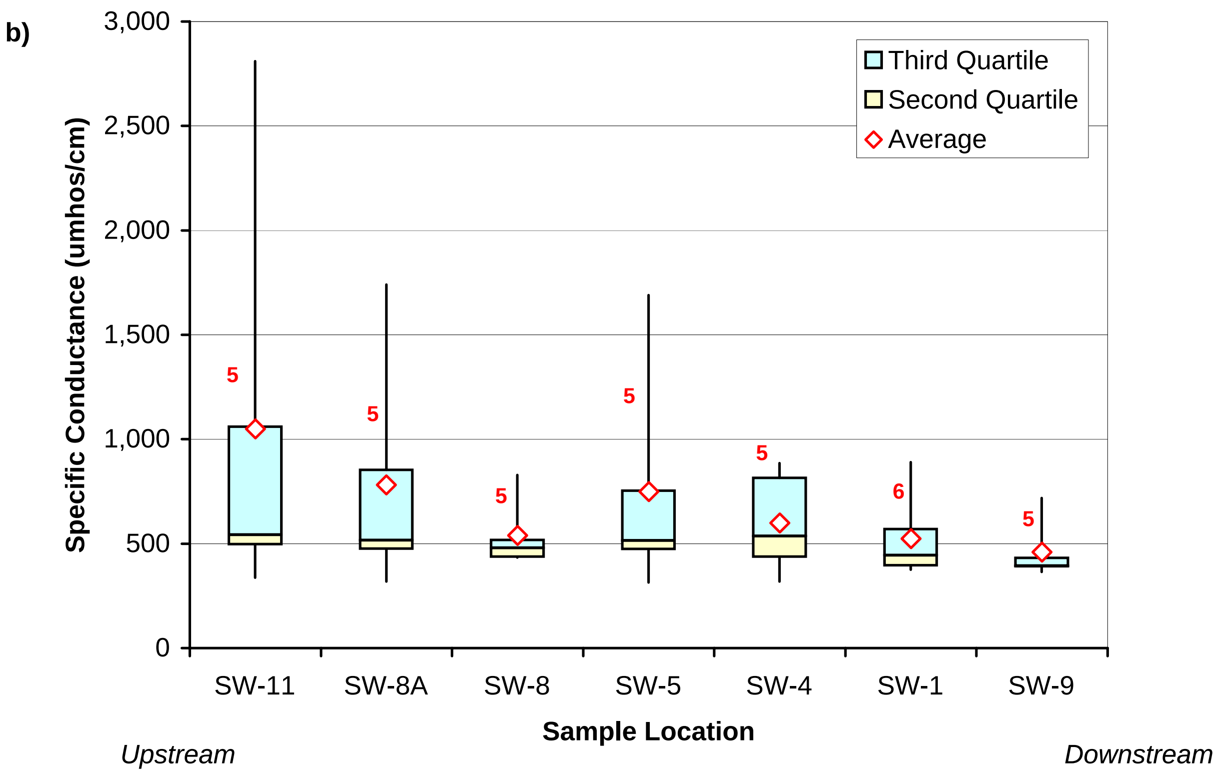
Note: 5 = Denotes number of data points represented.

GEOMEGA 8/4/05 C03302C Olin-MMB Study	a) Chloride and b) sodium (dissolved) concentration distributions in Maple Meadow Brook surface water.	**Figure** 41

a)

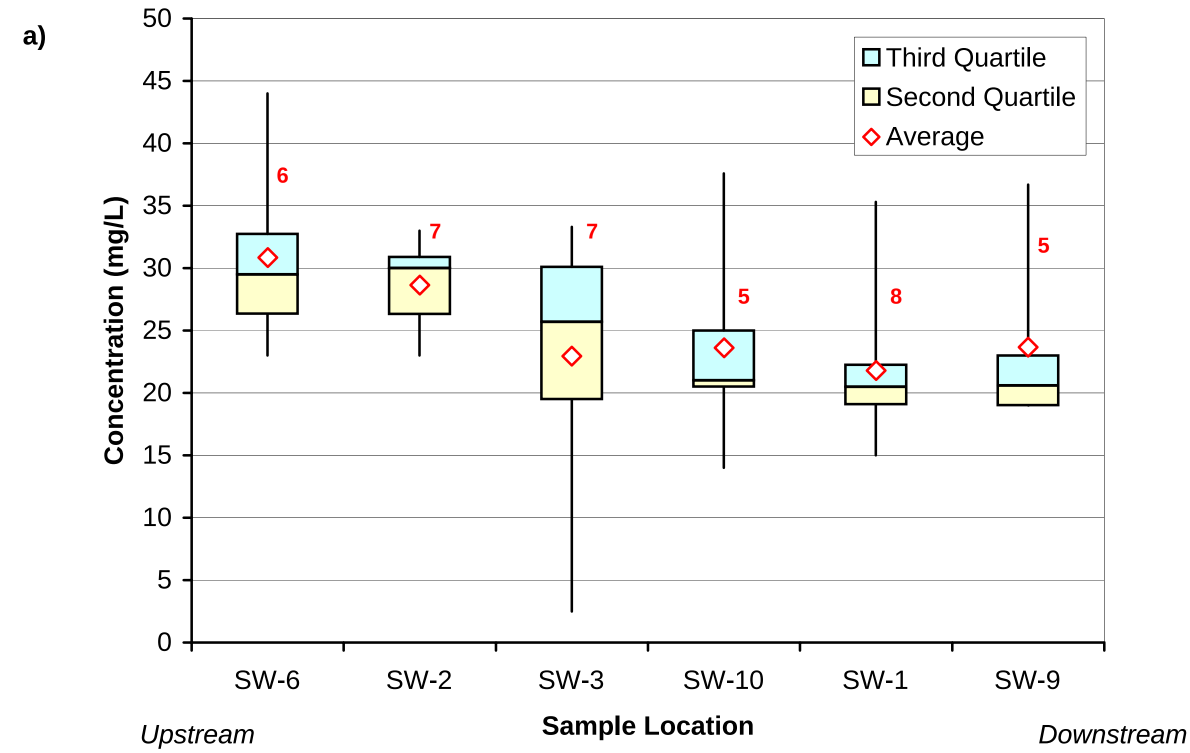


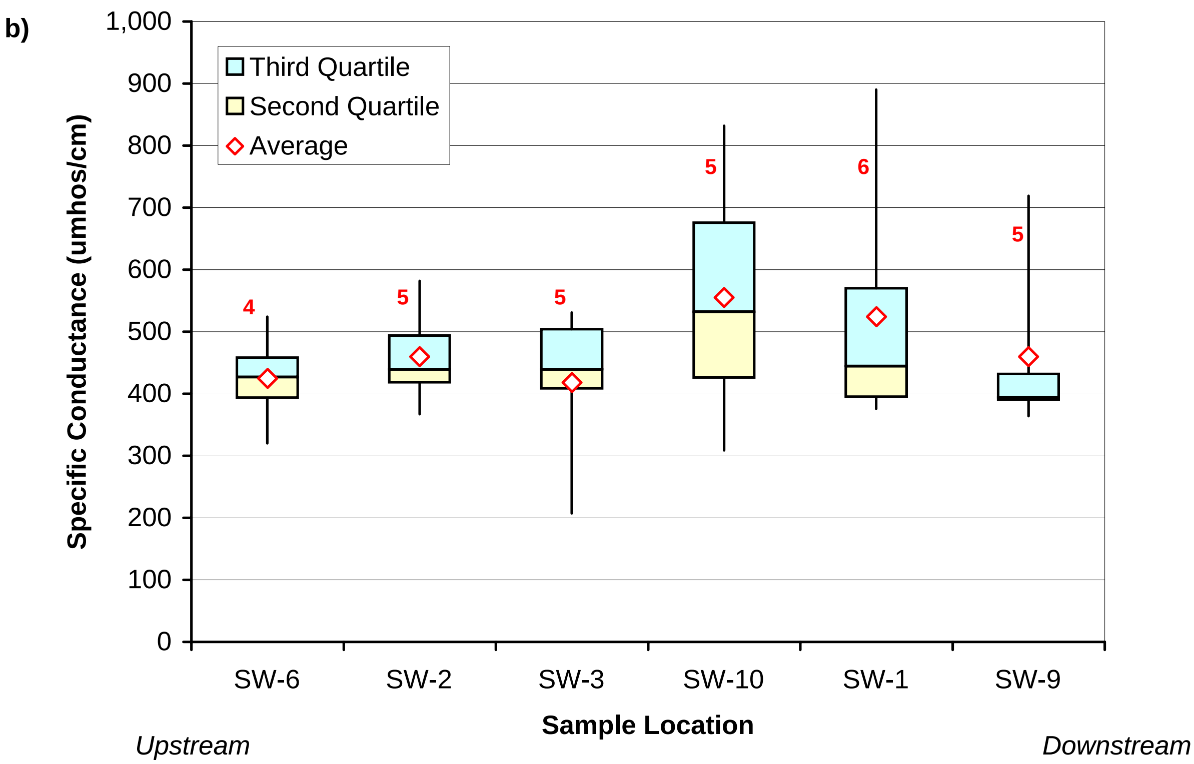
b)



Note: **5** = Denotes number of data points represented.

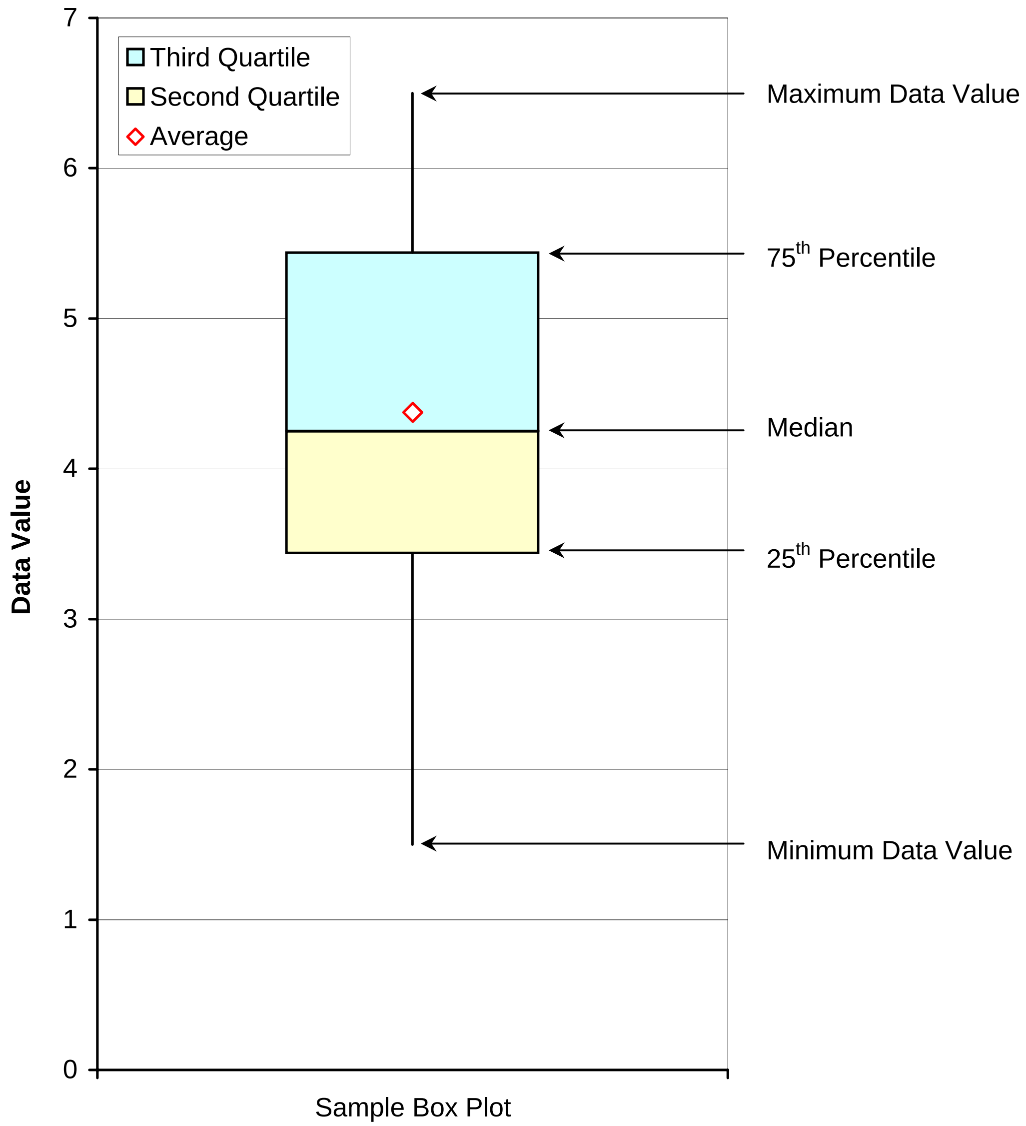
GEOMEGA	a) Calcium (dissolved) and b) specific conductance concentration distributions in Sawmill Brook surface water.	**Figure** 42
8/4/05		
C03302C Olin-MMB Study		





Note: 5 = Denotes number of data points represented.

GEOMEGA 8/4/05 C03302C Olin-MMB Study	a) Calcium (dissolved) and b) specific conductance concentration distributions in Maple Meadow Brook surface water.	**Figure** 43



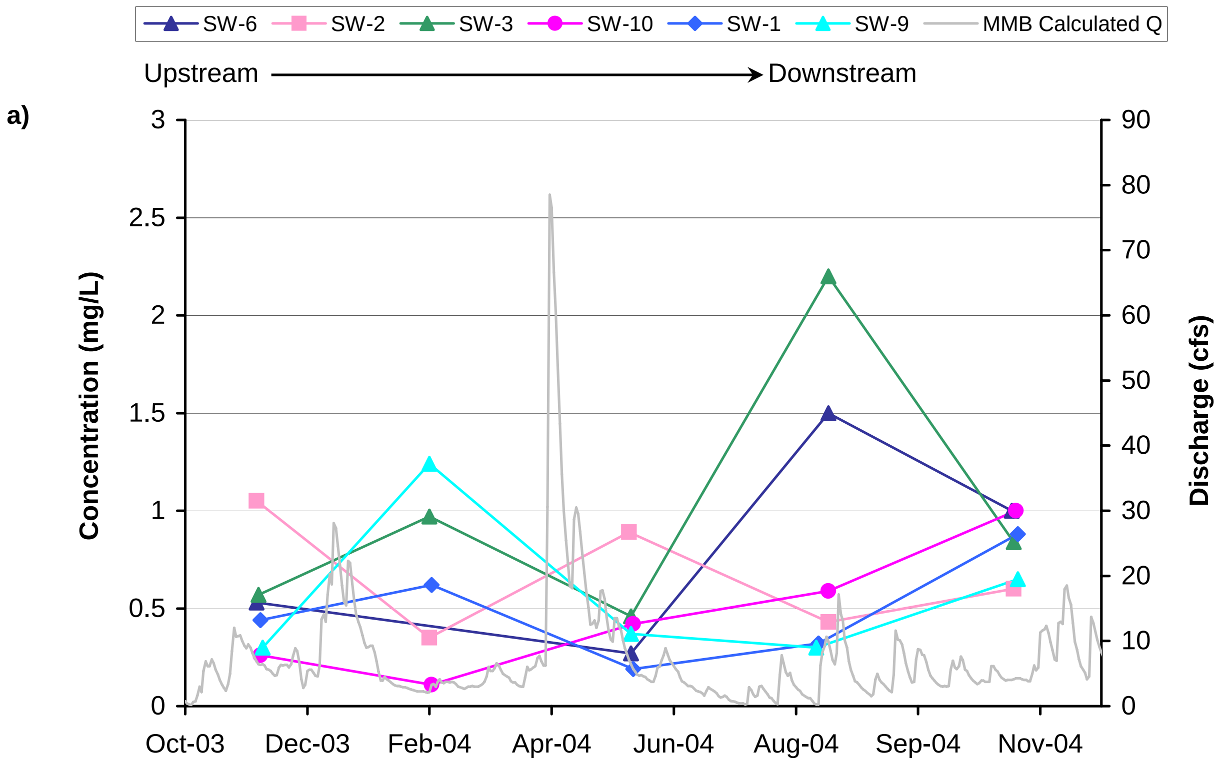
GEOMEGA

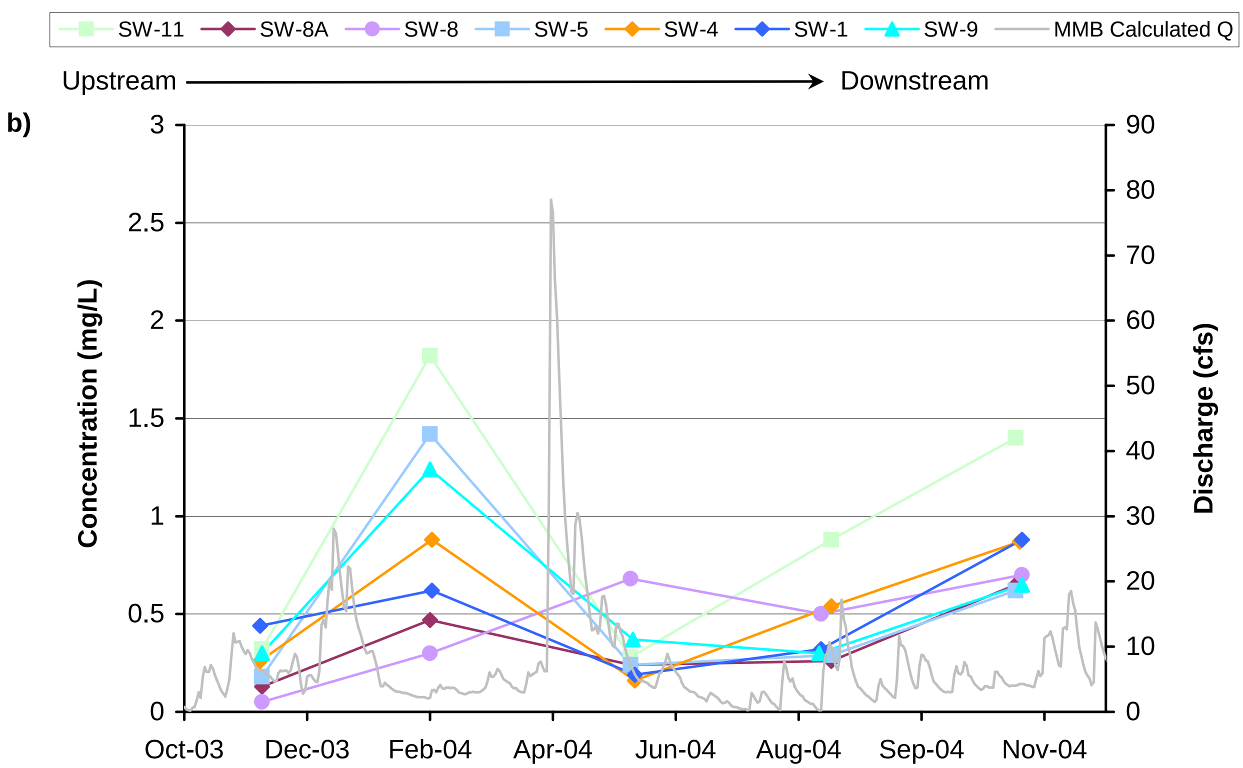
8/4/05

C03302C
Olin-MMB Study

Sample box plot.

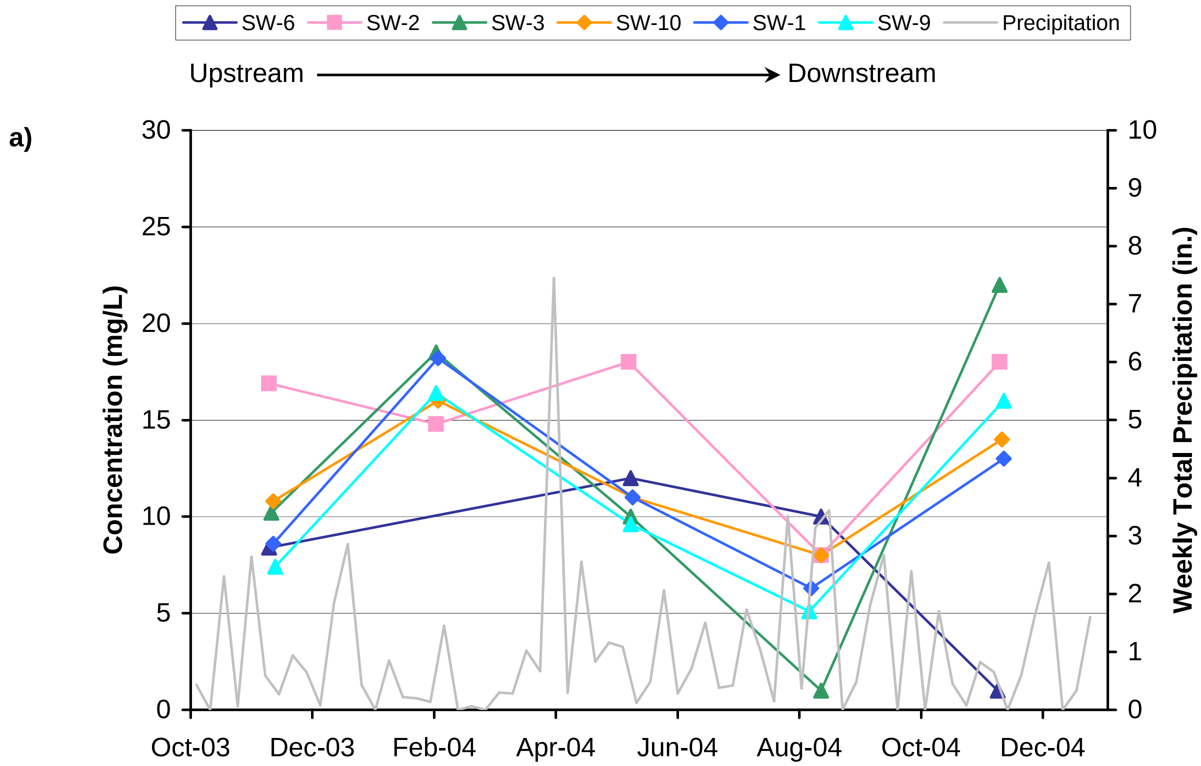
Figure
44

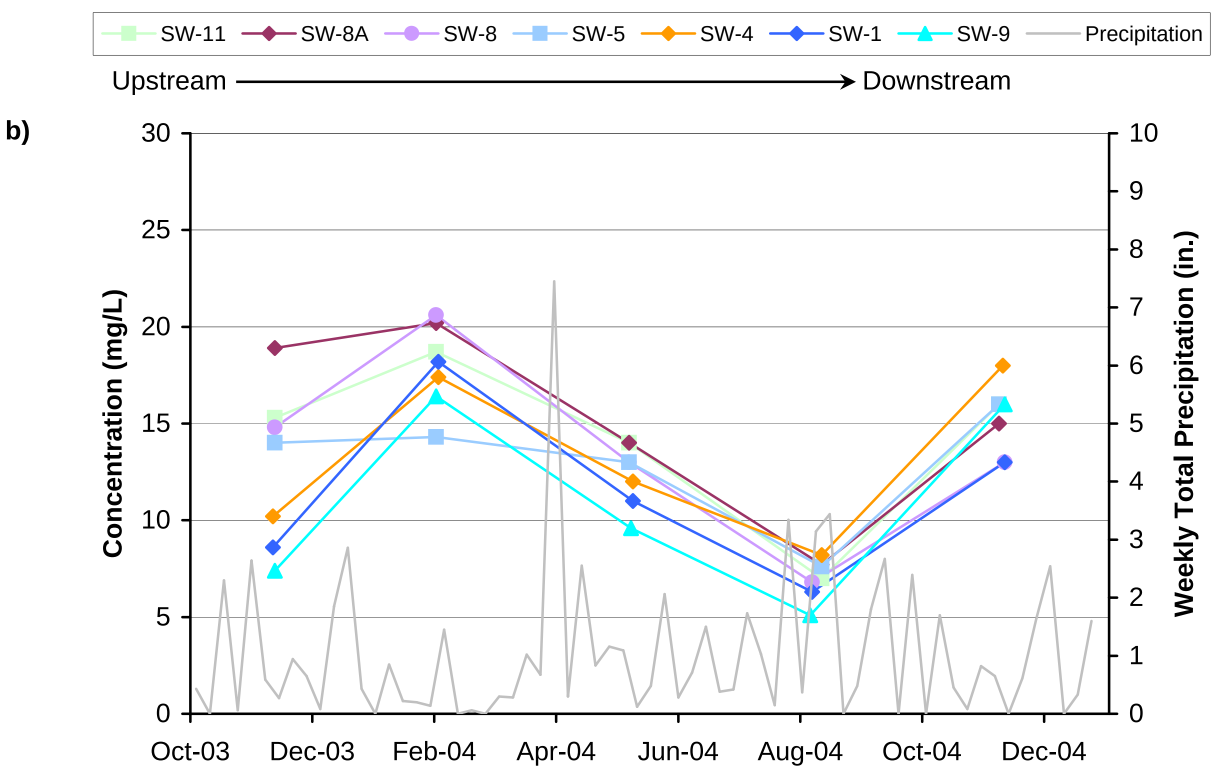




GEOMEGA 8/4/05 C03302C Olin-MMB Study	Ammonia concentrations in a) Maple Meadow Brook and b) Sawmill Brook versus calculated Maple Meadow Brook discharge.	**Figure** 45

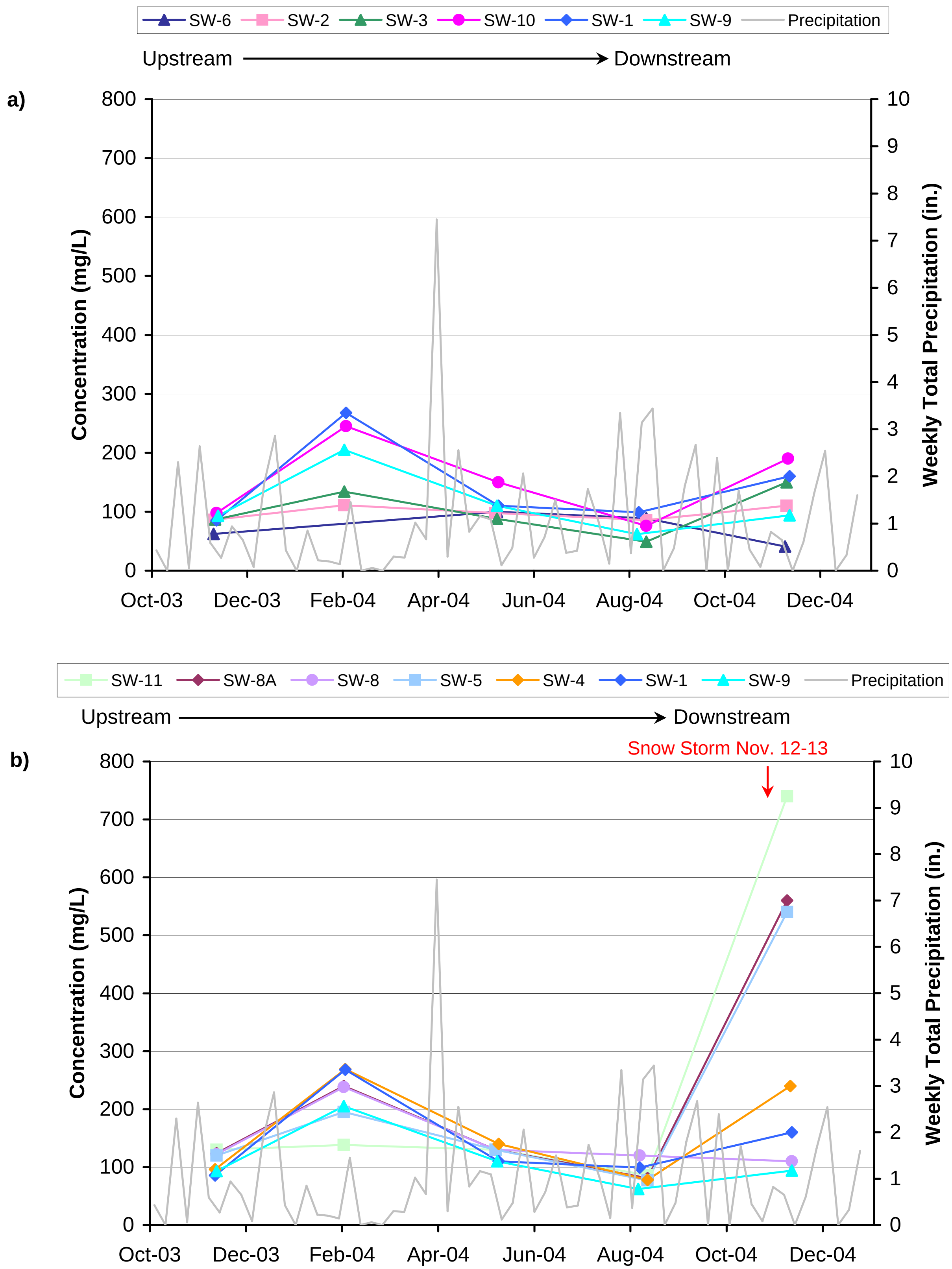
JM o:\Olin\WBV CD Figures\MMB SW results with Box plots 6-05 B (version 2).xls





GEOMEGA 8/4/05 C03302C Olin-MMB Study	Sulfate concentrations in a) Maple Meadow Brook and b) Sawmill Brook surface water versus weekly total precipitation.	**Figure** 46

JM o:\Olin\WBV CD Figures\C vs T Plots.xls



GEOMEGA

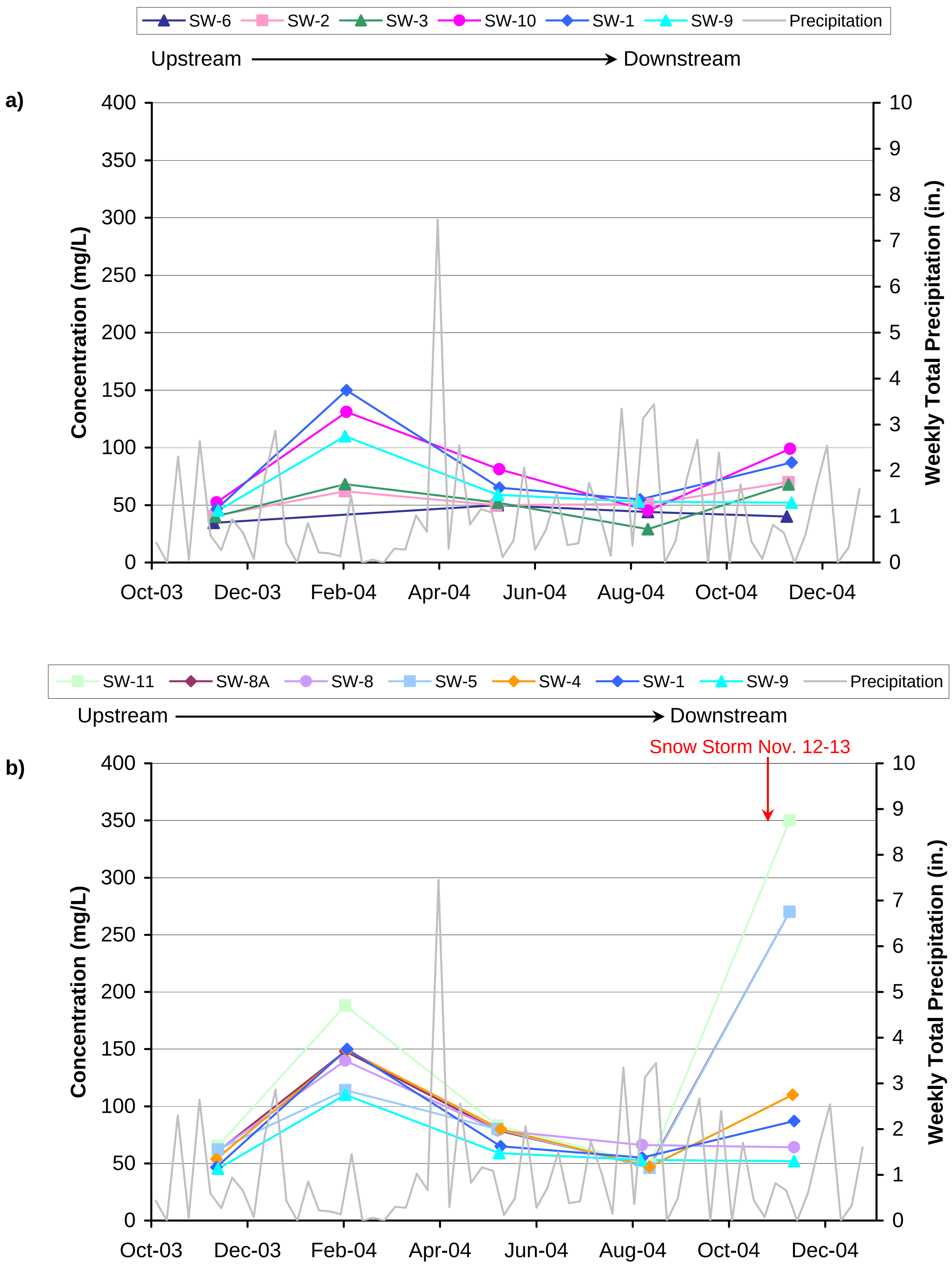
8/4/05

C03302C
Olin-MMB Study

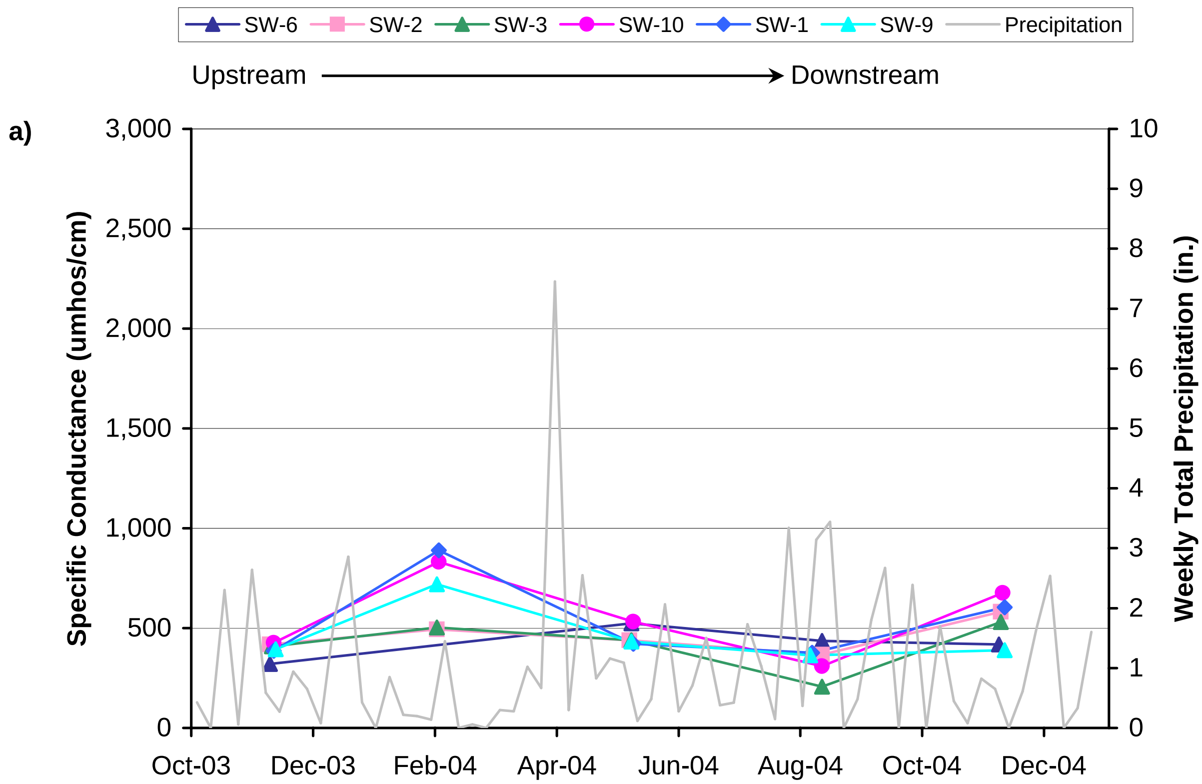
Chloride concentrations in a) Maple Meadow Brook and b) Sawmill Brook surface water versus weekly total precipitation.

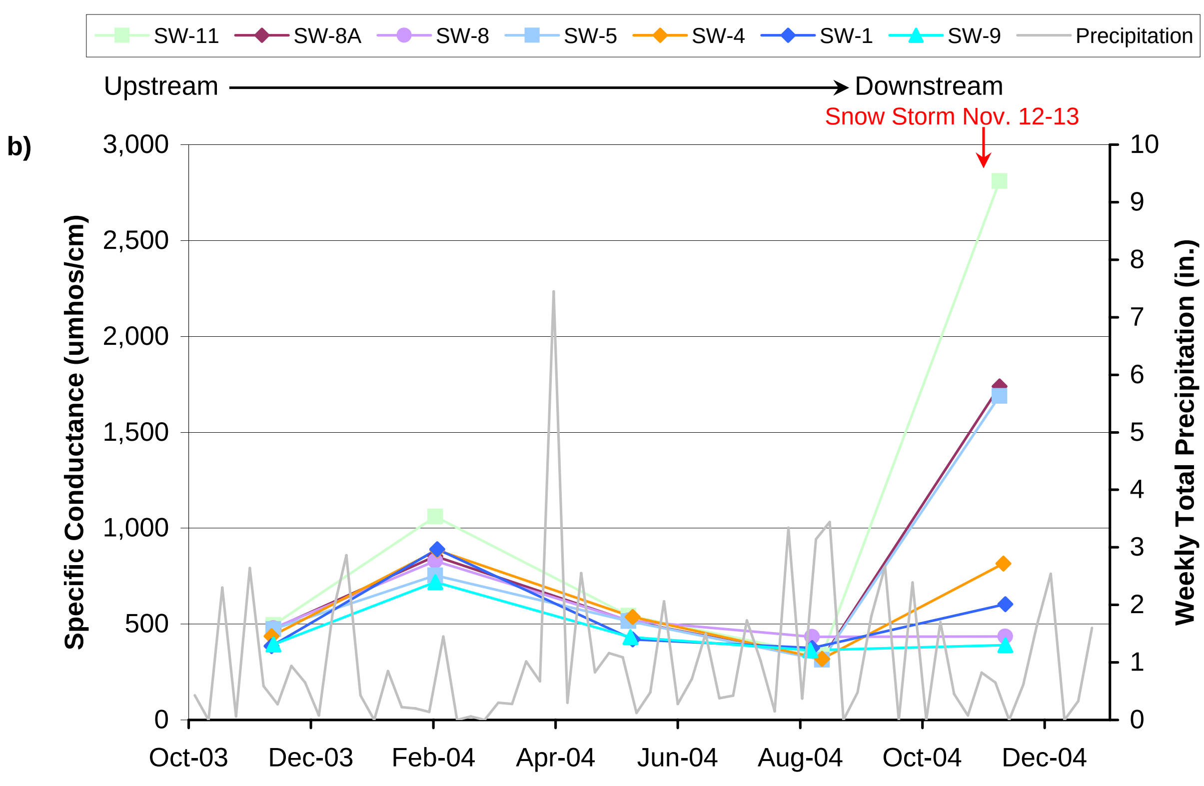
Figure
47

JM o:\Olin\WBV CD Figures\C vs T Plots.xls



GEOMEGA 8/4/05 C03302C Olin-MMB Study	Sodium concentrations in a) Maple Meadow Brook and b) Sawmill Brook surface water versus weekly total precipitation.	**Figure** 48





GEOMEGA

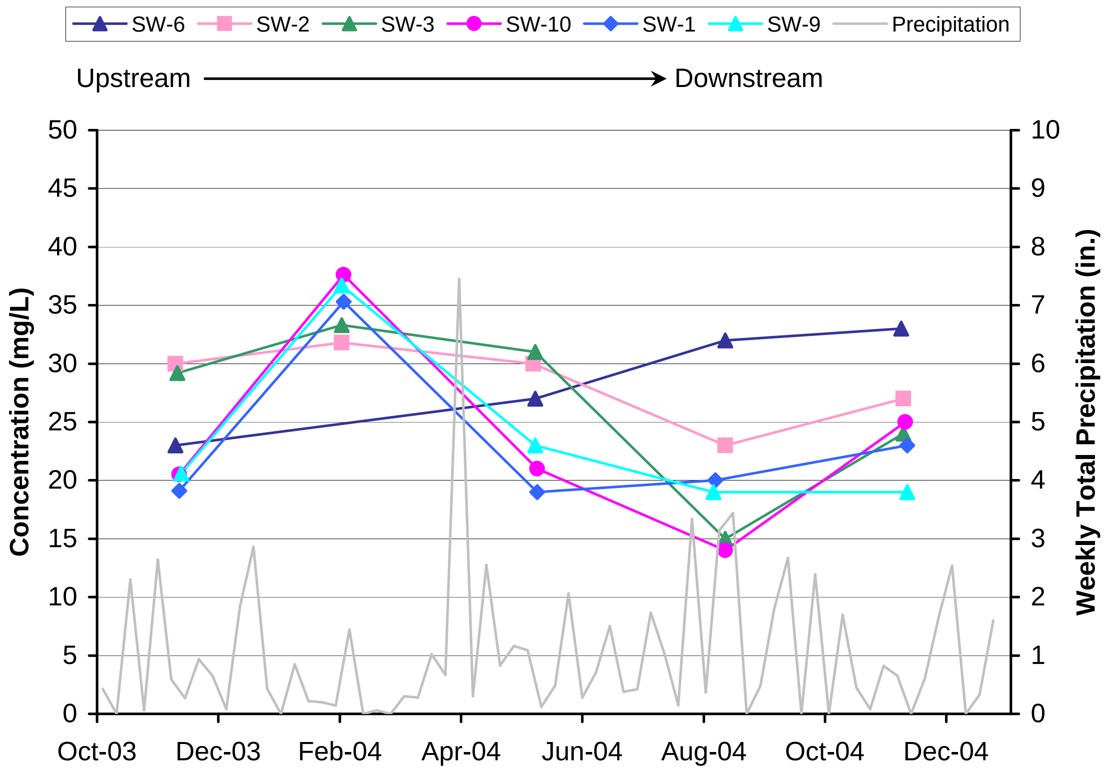
8/4/05

C03302C
Olin-MMB Study

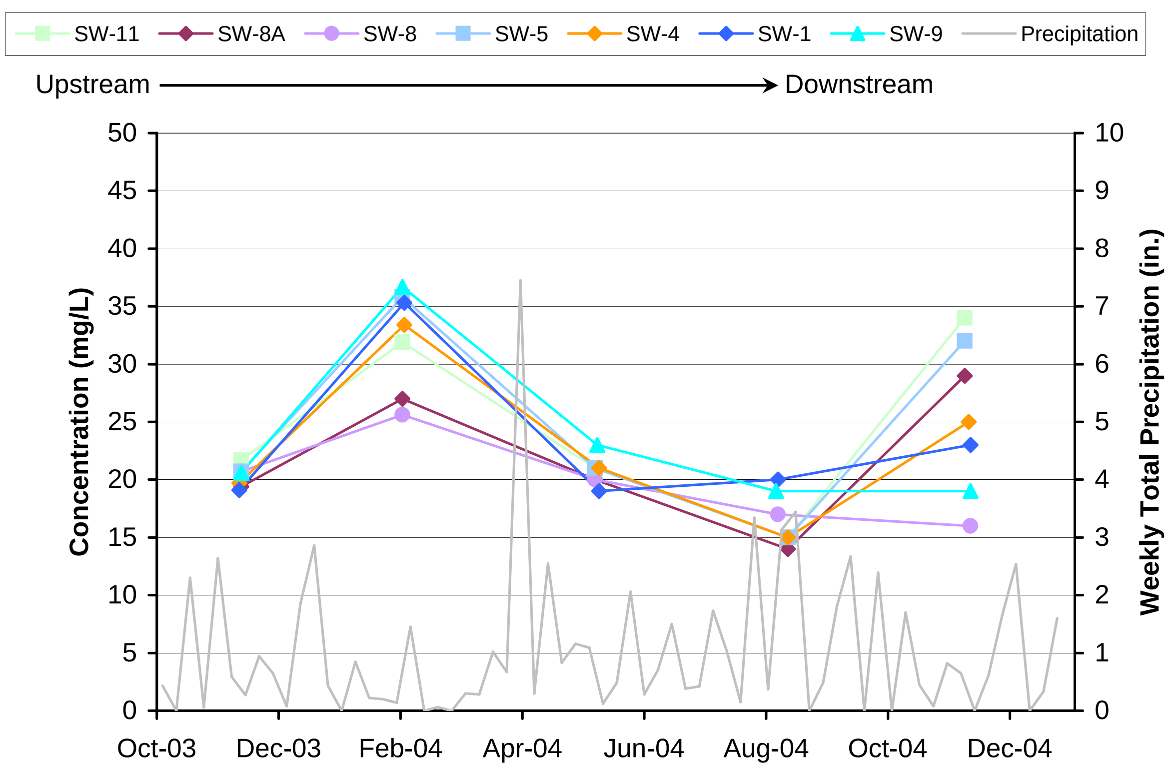
Specific conductance in a) Maple Meadow Brook and b) Sawmill Brook surface water versus weekly total precipitation.

Figure
49

a)

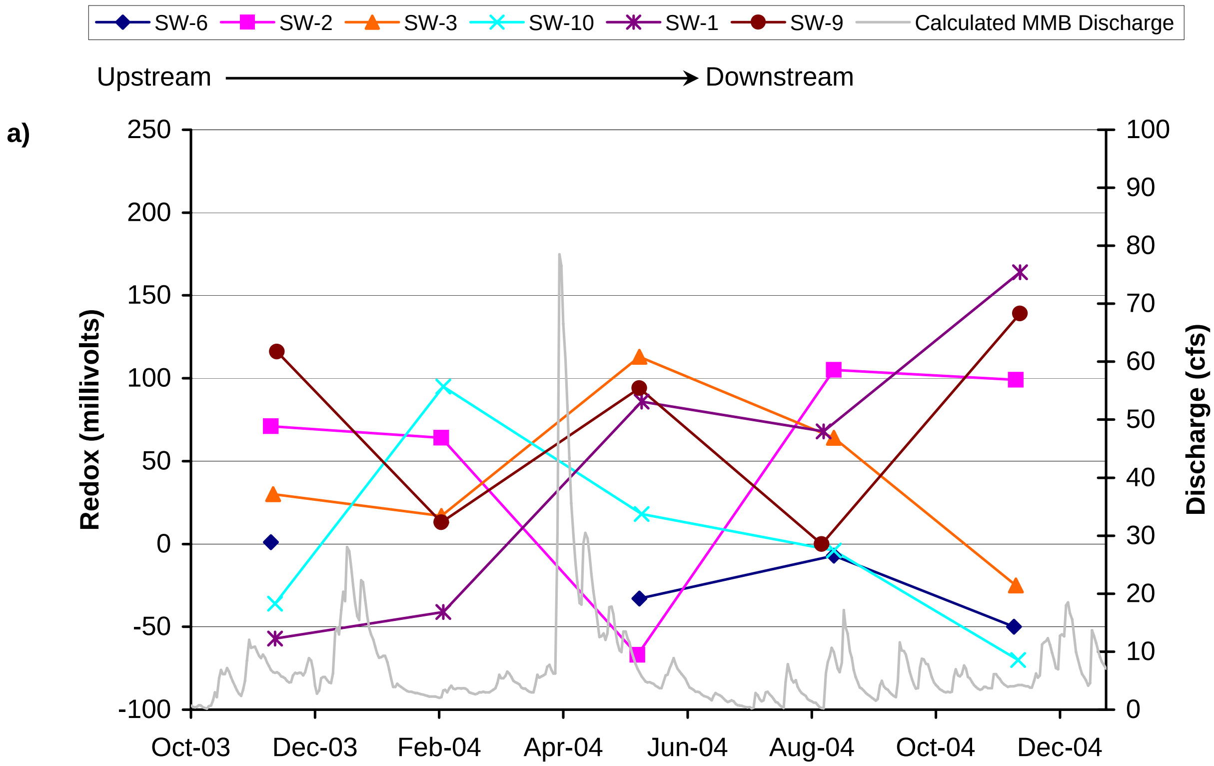


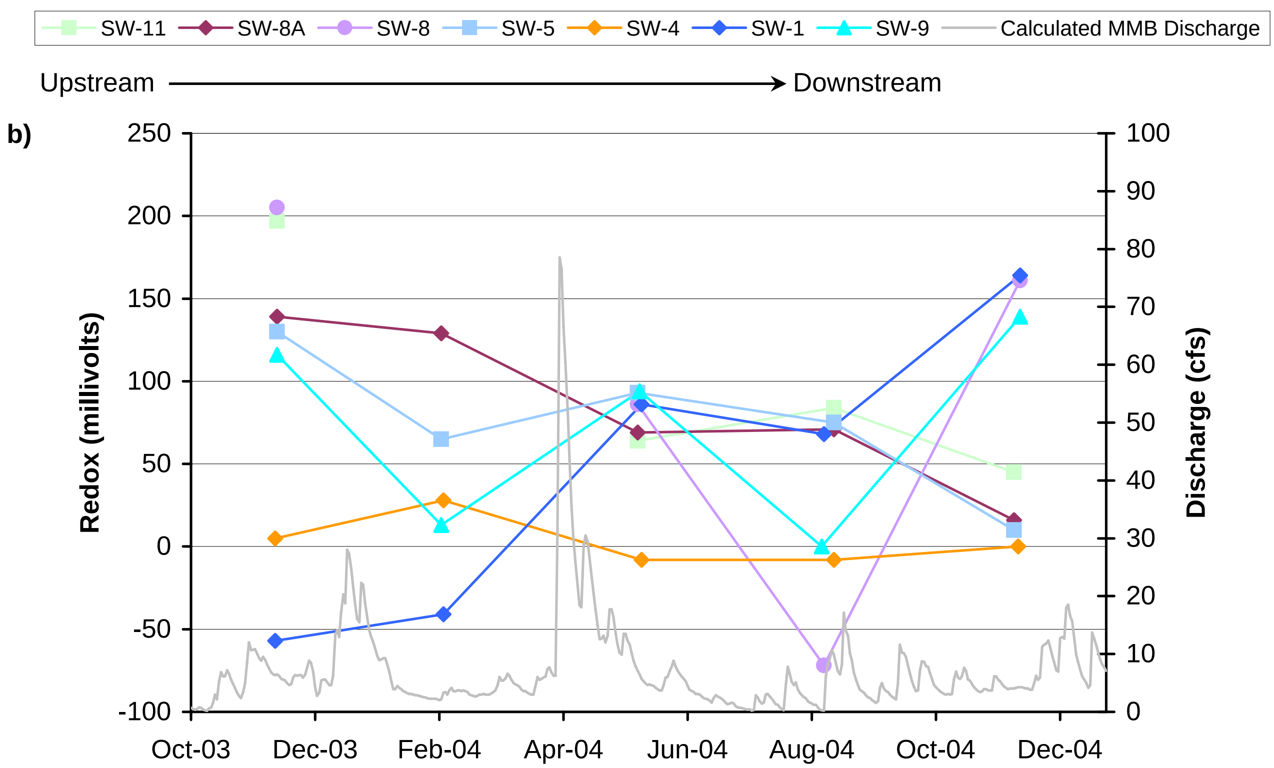
b)



GEOMEGA 8/4/05 C03302C Olin-MMB Study	Calcium concentrations in a) Maple Meadow Brook and b) Sawmill Brook surface water versus weekly total precipitation.	**Figure** 50

JM o:\Olin\WBV CD Figures\C vs T Plots.xls





GEOMEGA

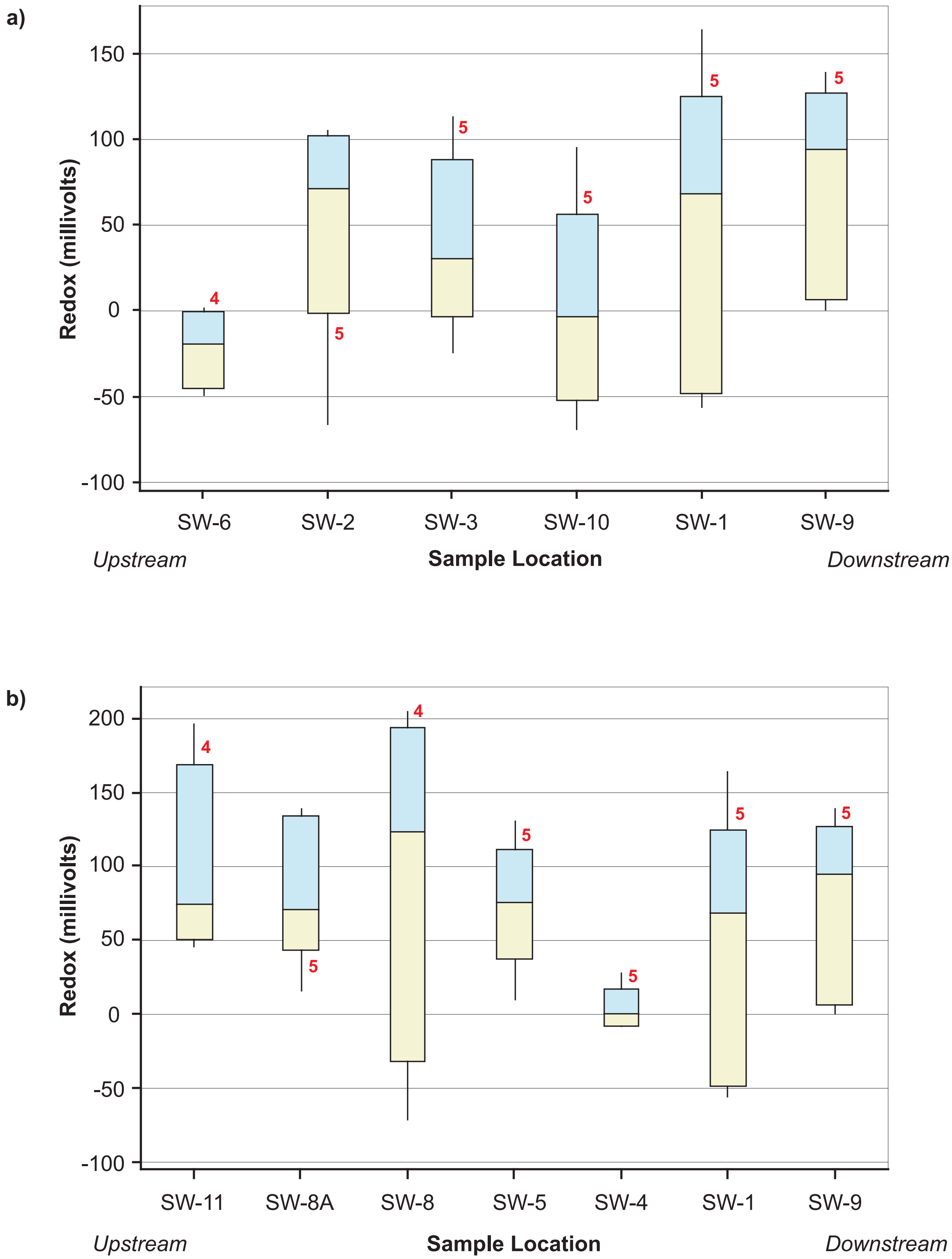
8/4/05

C03302C
Olin-MMB Study

Measured redox conditions in a) Maple Meadow Brook and b) Sawmill Brook surface water versus calculated Maple Meadow Brook discharge.

Figure
51

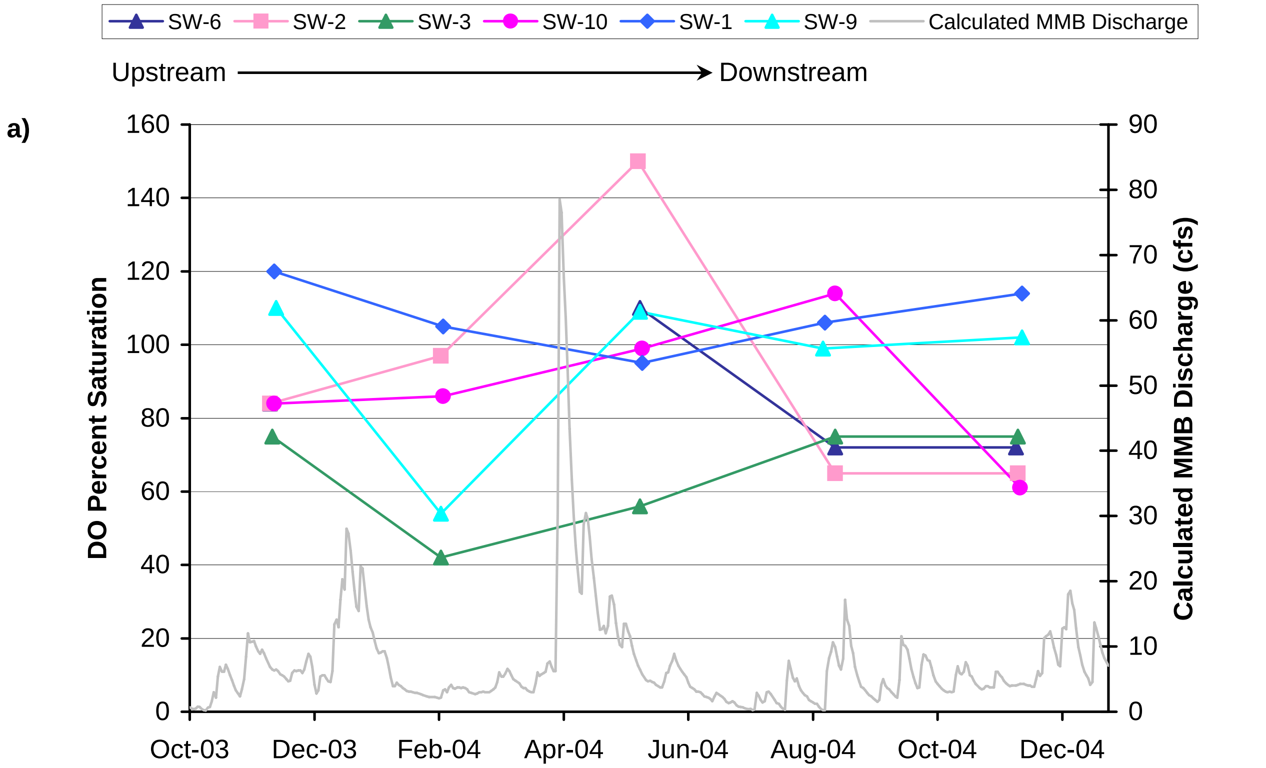
JM o:\Olin\WBV CD Figures\DO Redox.xls

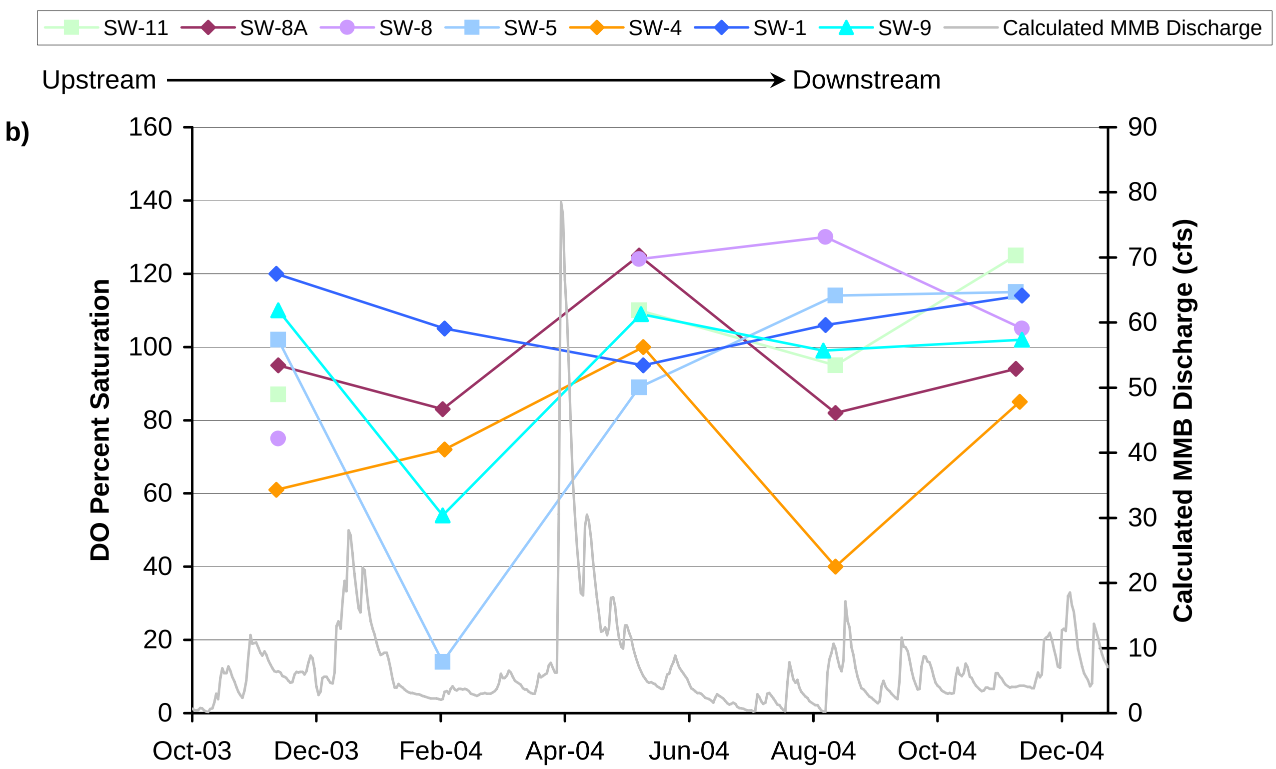


Note: 5 = Denotes number of data points represented.

GEOMEGA	Relative redox conditions in a) Maple Meadow Brook and b) Sawmill Brook surface water. (Fourth quarter 2003 through fourth quarter 2004.)	**Figure** 52
8/4/05		
C03302C Olin-MMB Study		

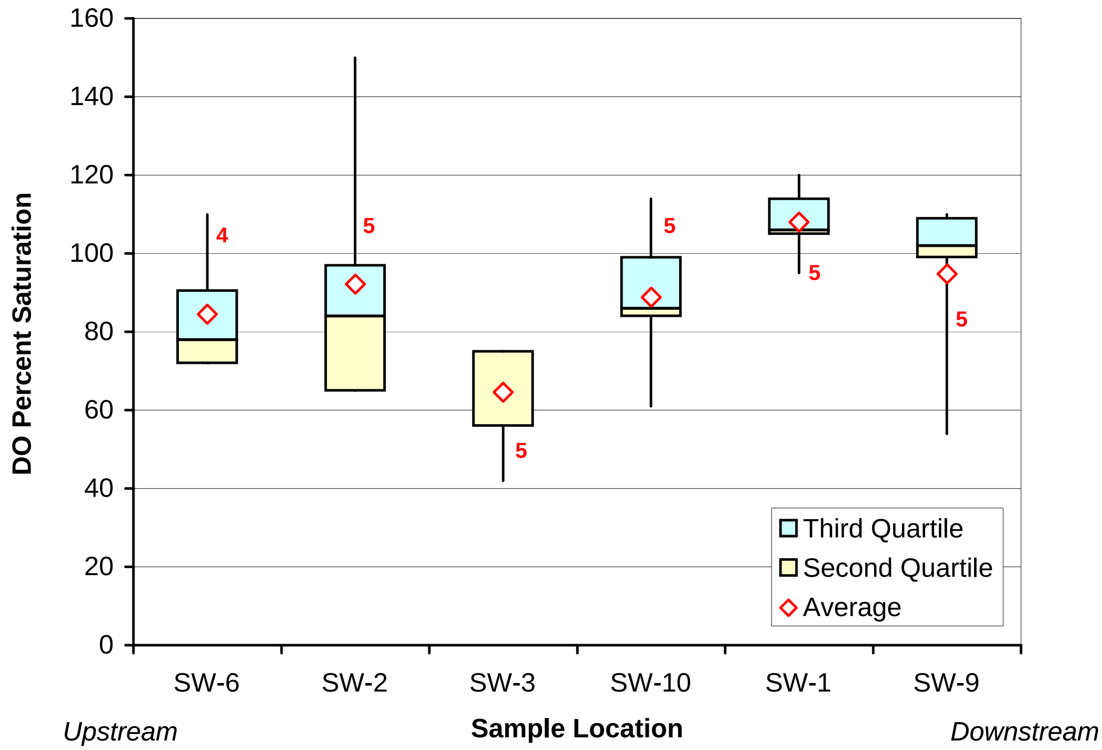
JM o:\Olin\WBV CD Figures\Redox Conditions.ai



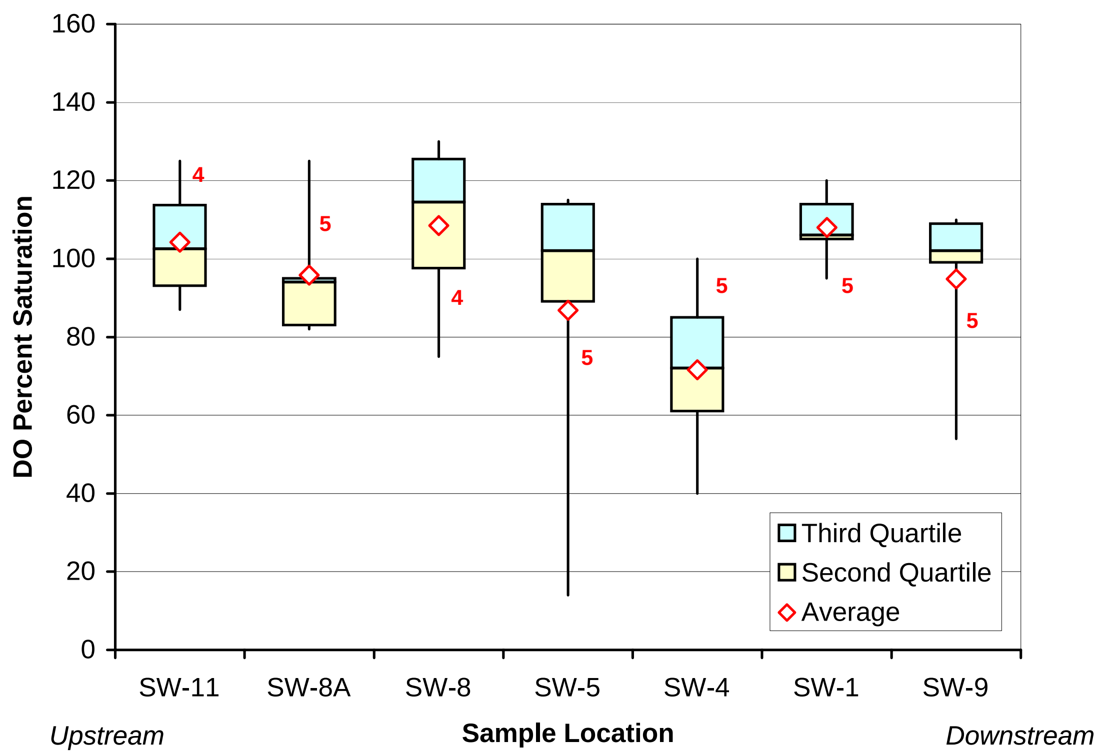


GEOMEGA 8/4/05 C03302C Olin-MMB Study	Dissolved oxygen concentrations as a percentage of saturation in a) Maple Meadow Brook and b) Sawmill Brook surface water versus calculated Maple Meadow Brook discharge.	**Figure** 53

a)

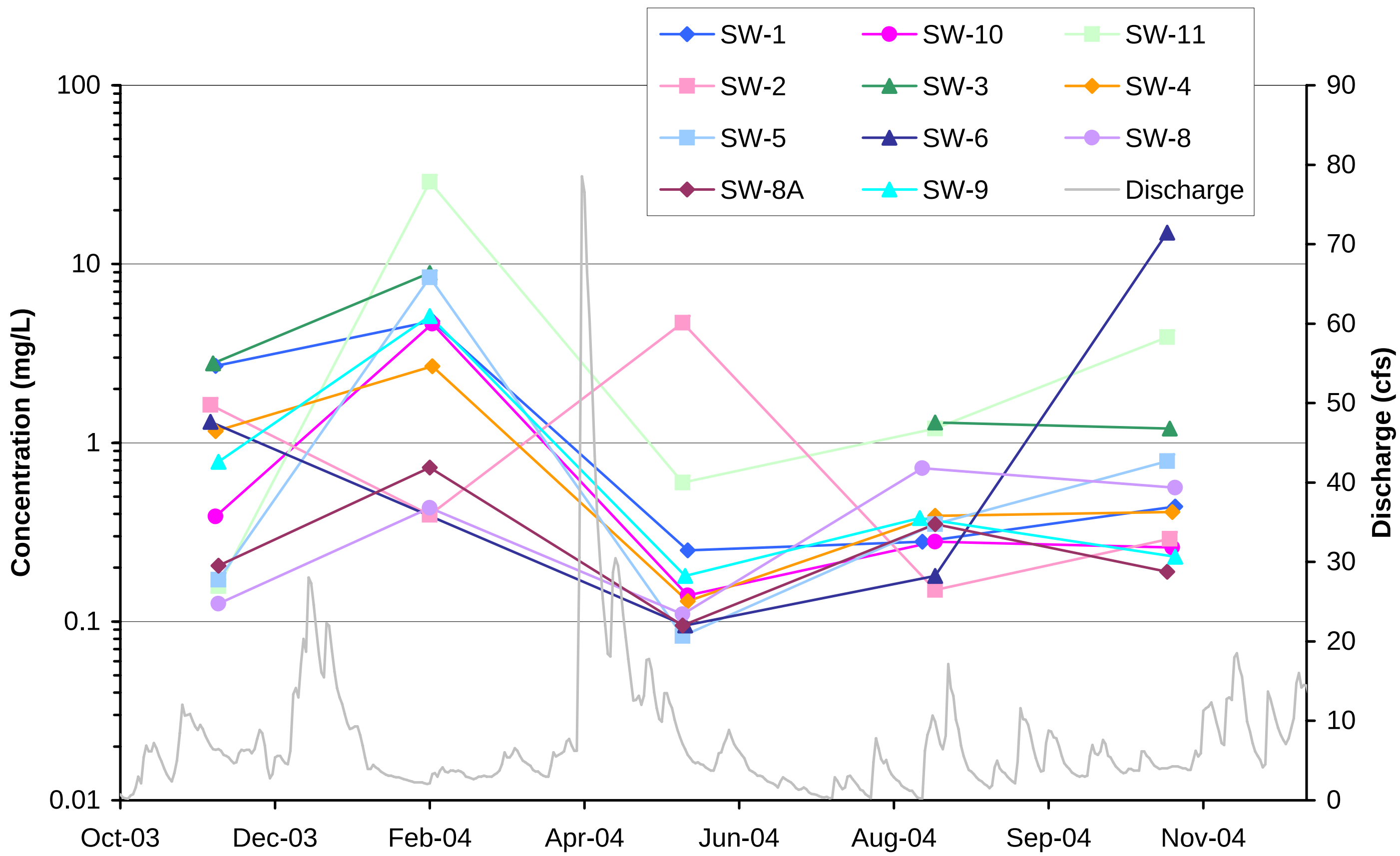


b)



Note: 5 = Denotes number of data points represented.

GEOMEGA 8/4/05 C03302C Olin-MMB Study	Dissolved oxygen concentration distributions as a percentage of saturation in a) Maple Meadow Brook and b) Sawmill Brook surface water.	**Figure** 54



GEOMEGA

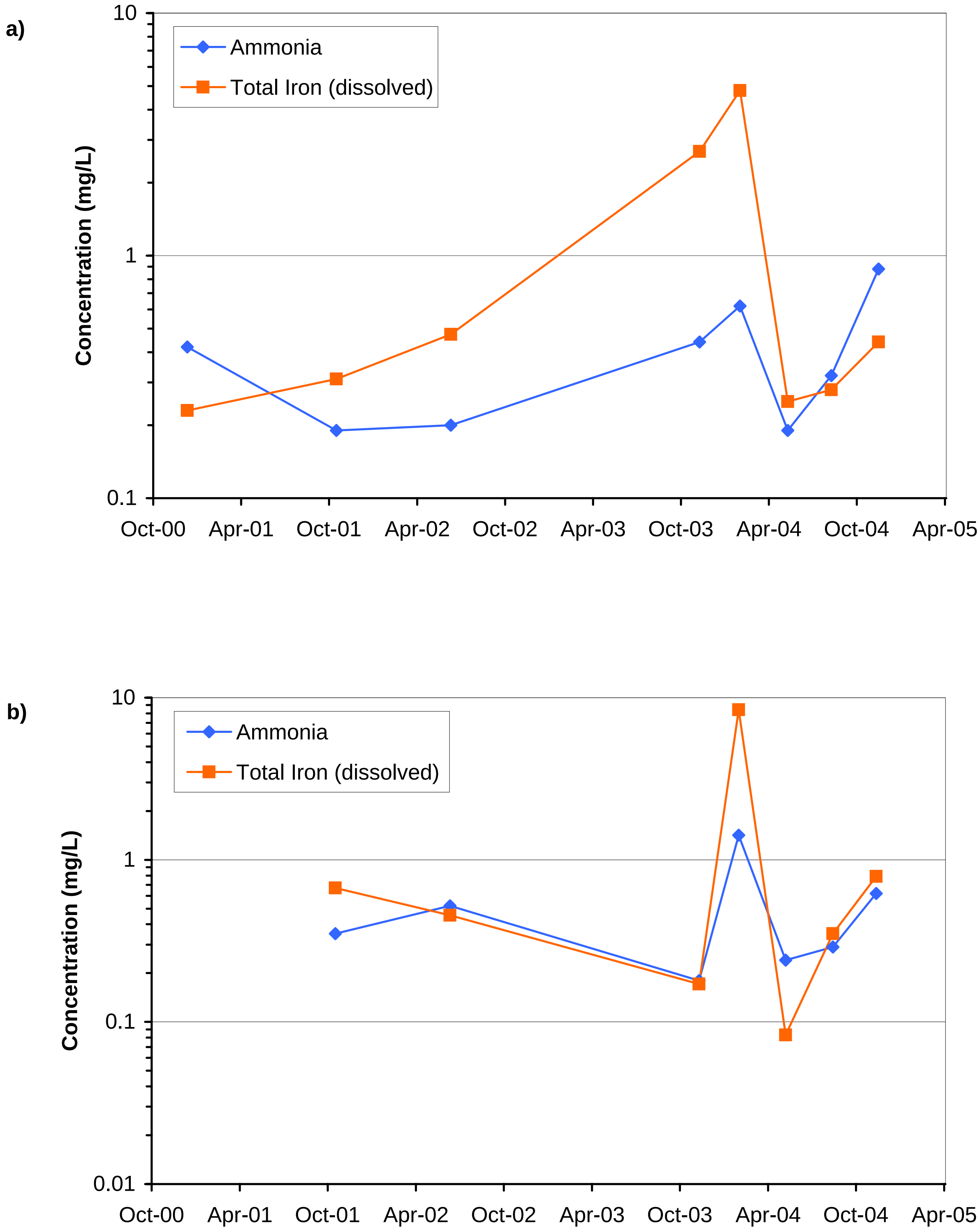
8/4/05

C03302C
Olin-MMB Study Area

Total iron (dissolved) concentrations at all Maple Meadow Brook and Sawmill Brook surface water sample locations versus calculated Maple Meadow Brook discharge.

Figure 55

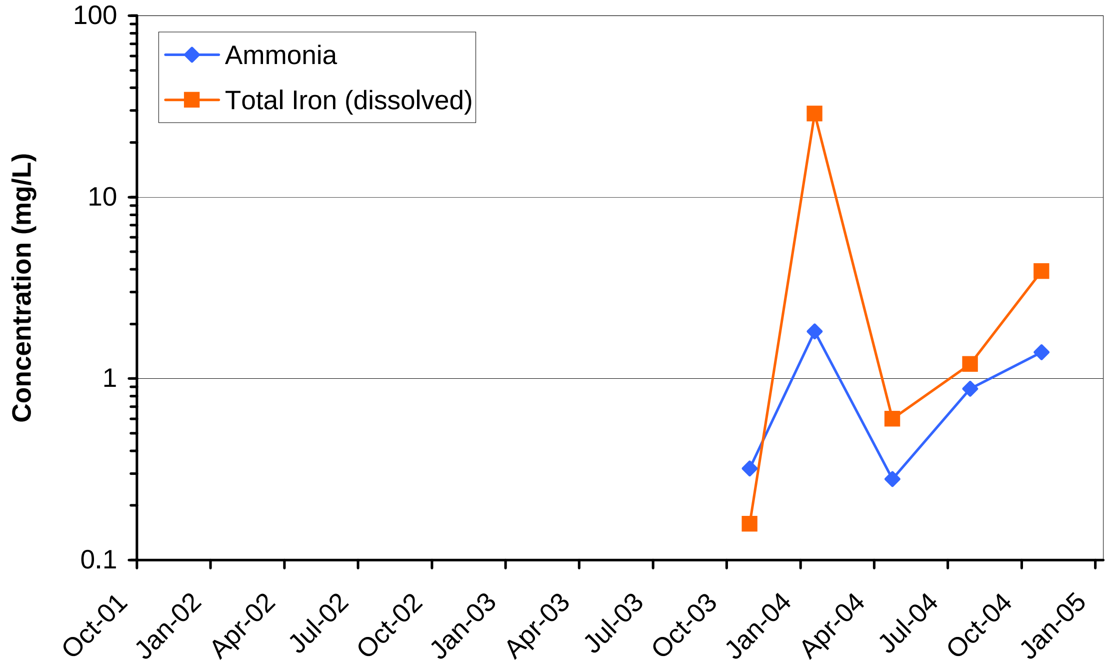
JM o:\Olin\WBV CD Figures\Max Dupe data.xls



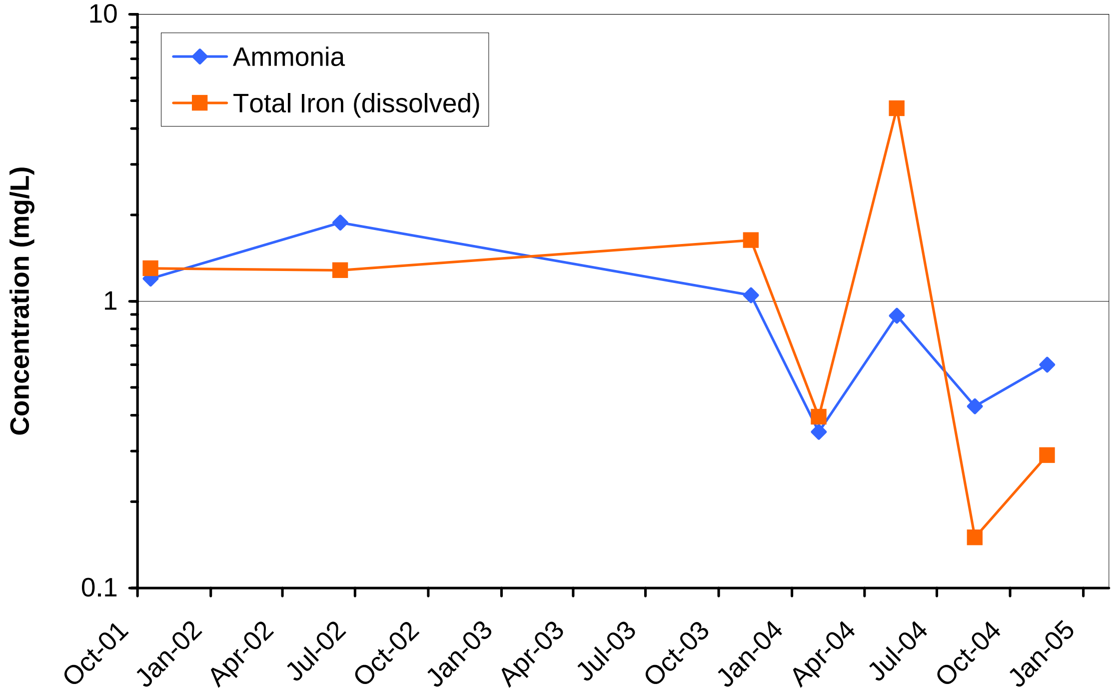
GEOMEGA 8/4/05 C03302C Olin-MMB Study	Ammonia versus total iron (dissolved) concentrations at locations a) MMB/SW-1 and b) SMB/SW-5.	**Figure** 56

JM o:\Olin\WBV CD Figures\Max Dupe data.xls

a)



b)



GEOMEGA

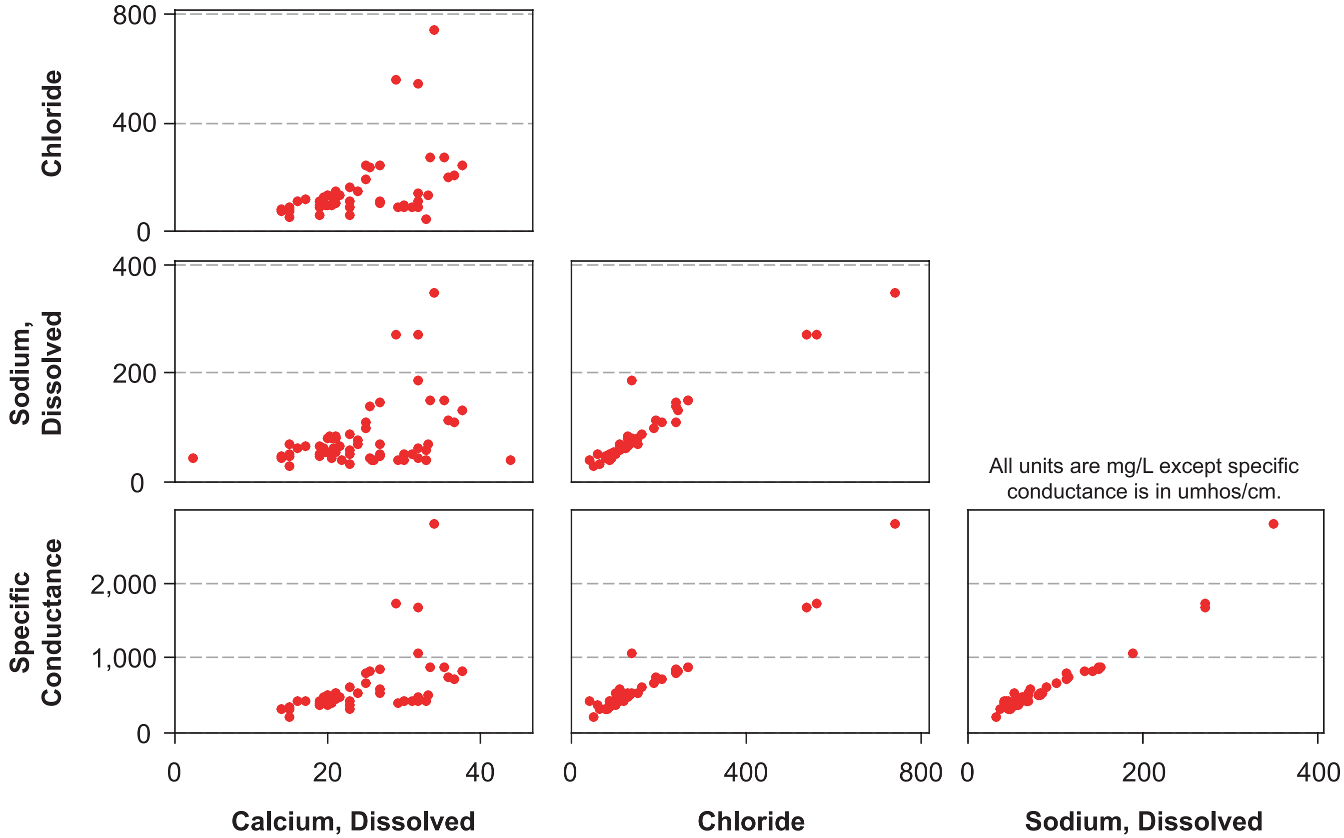
8/4/05

C03302C
Olin-MMB Study

Ammonia versus total iron (dissolved) concentrations at locations a) SMB/SW-11 and b) MMB/SW-2.

Figure
57

JM o:\Olin\WBV CD Figures\Max Dupe data.xls



GEOMEGA

8/4/05

C03302C
Olin-MMB Study

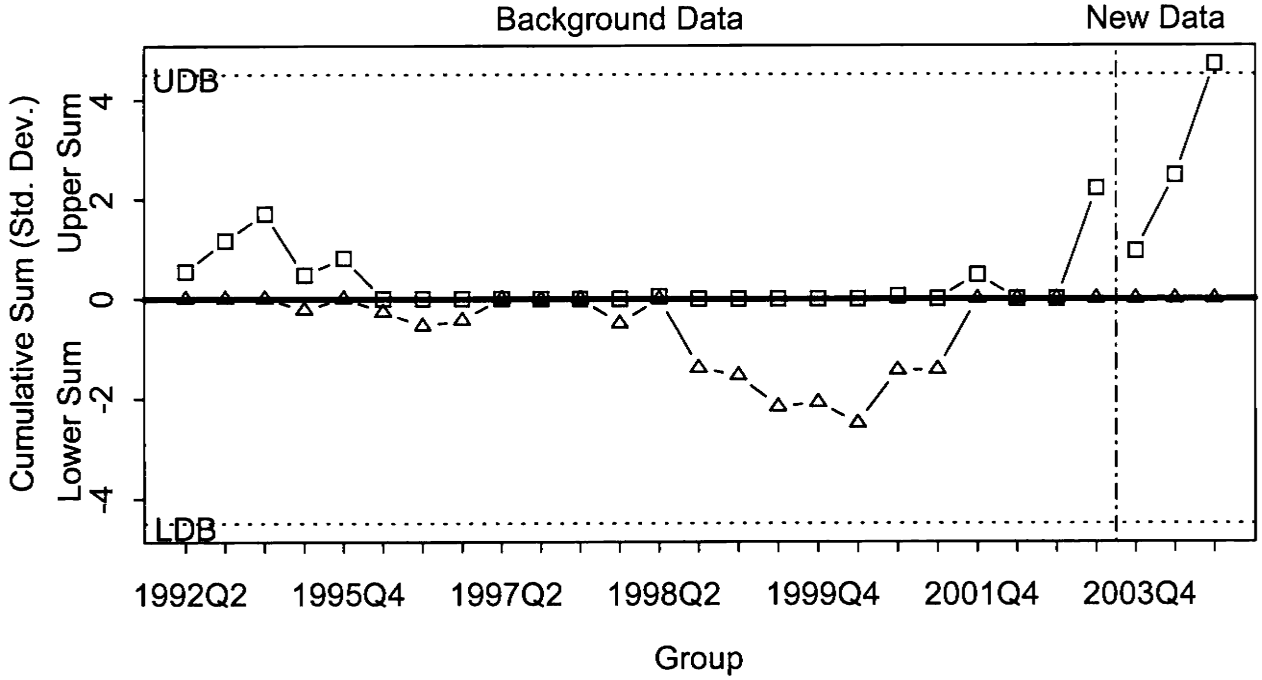
Relationship of calcium, chloride, sodium, and specific conductance in Maple Meadow Brook and Sawmill Brook surface waters.

Figure
58

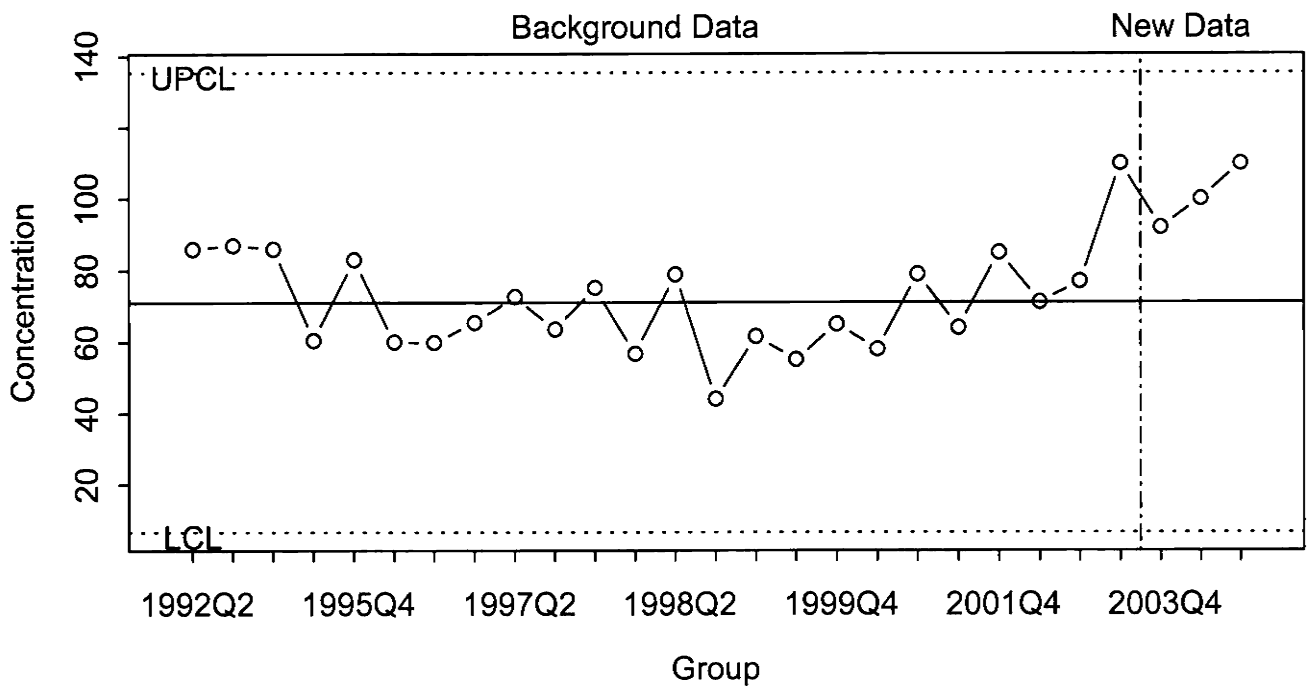
JM o:\Olin\WBV CD Figures\Matrix Plot CaClNaSC.ai

Appendix A

CUSUM CHART



Shewhart Chart

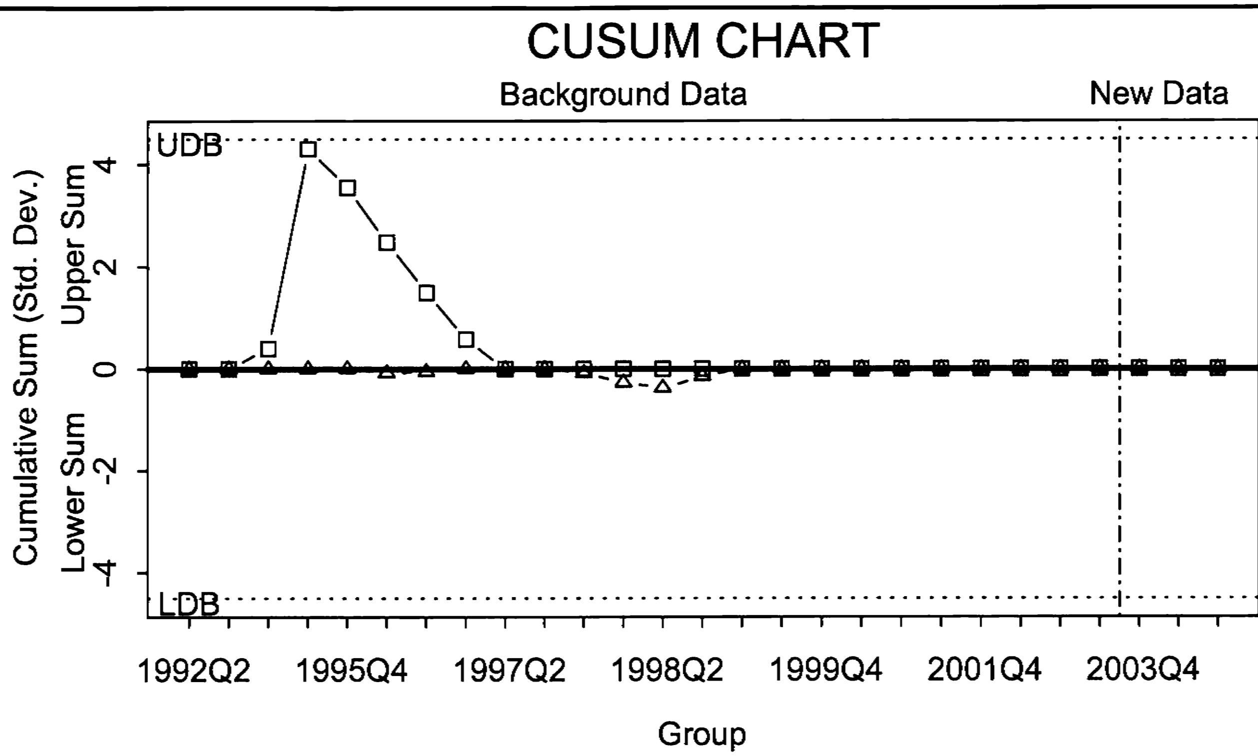


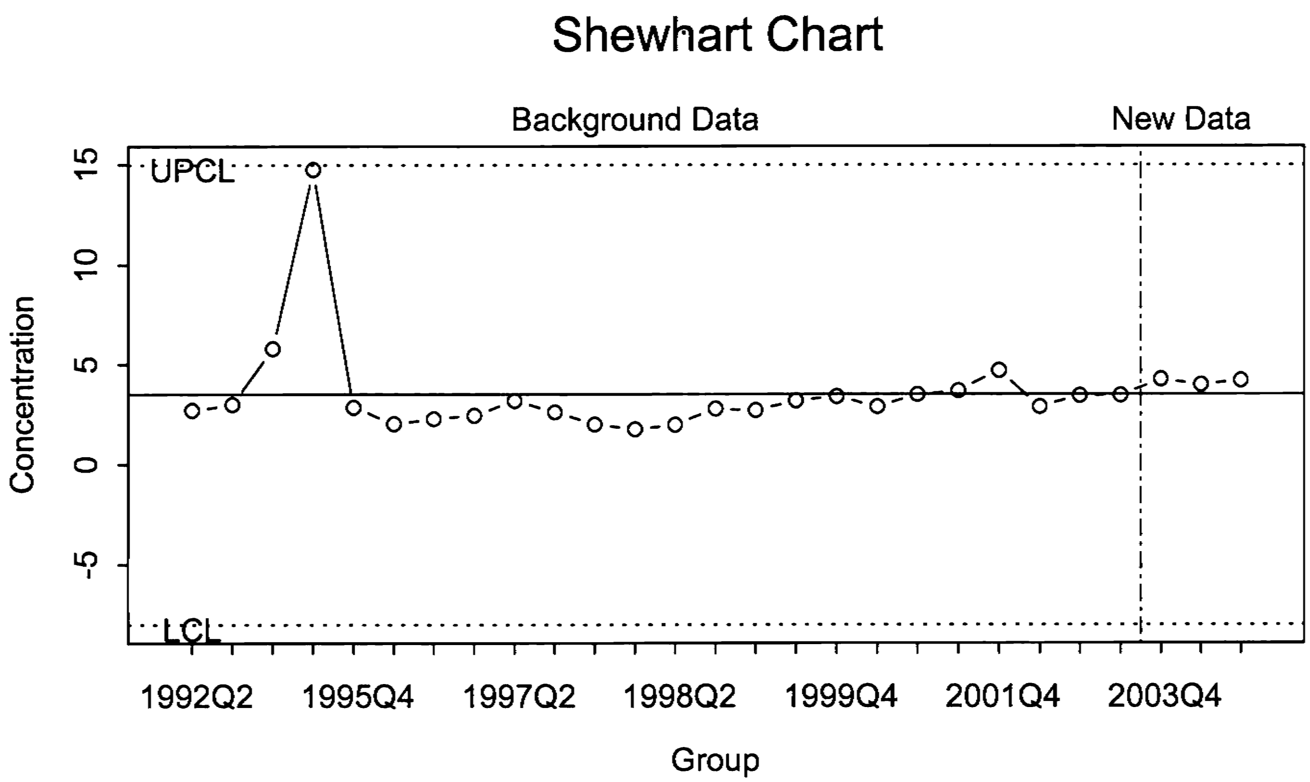
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-62D
Chloride
mg/l



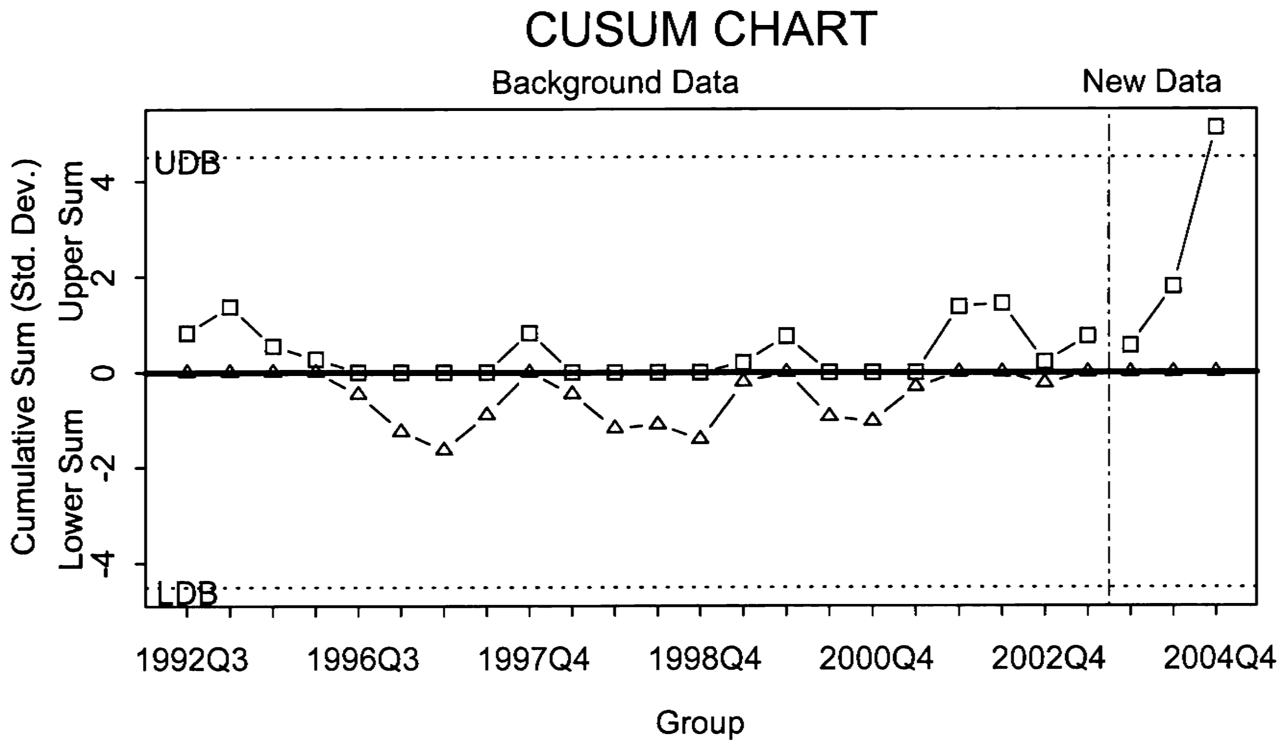


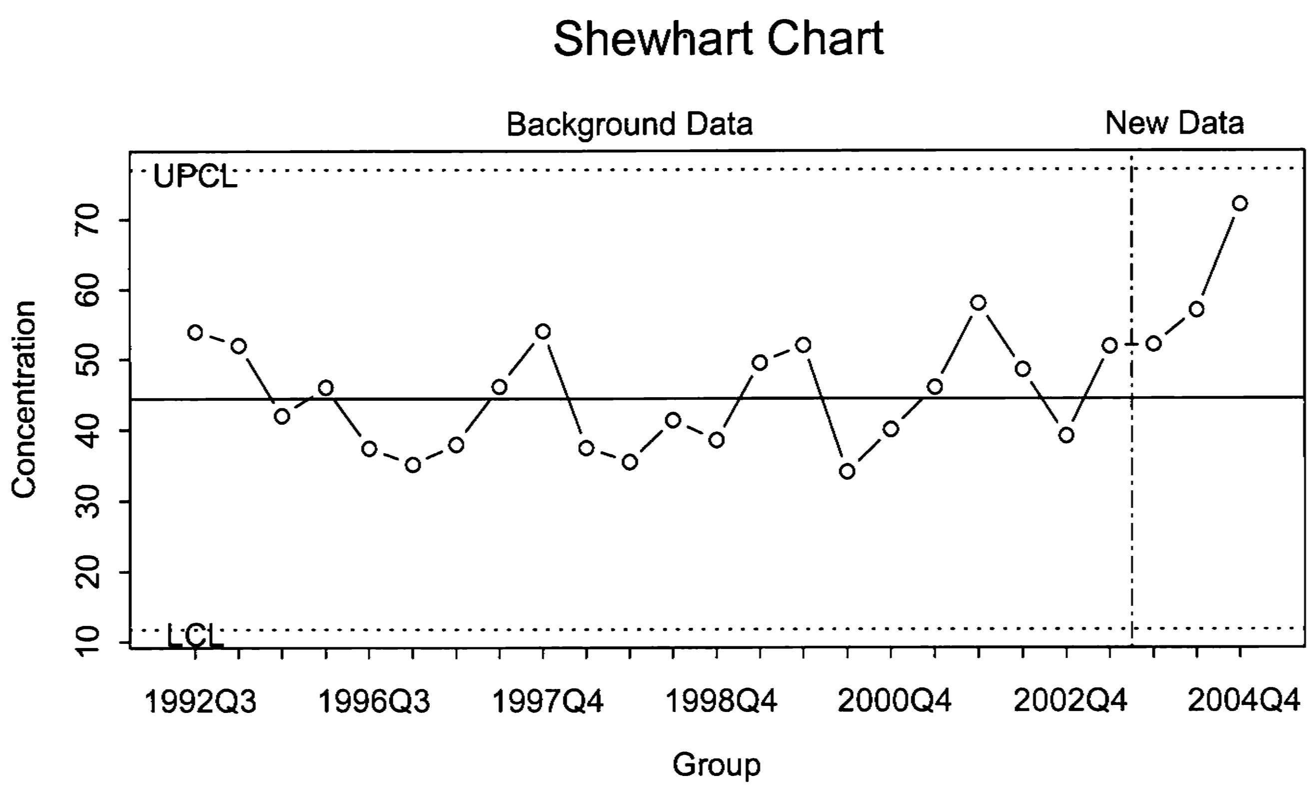
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-62D
Nitrogen, Ammonia
mg/l





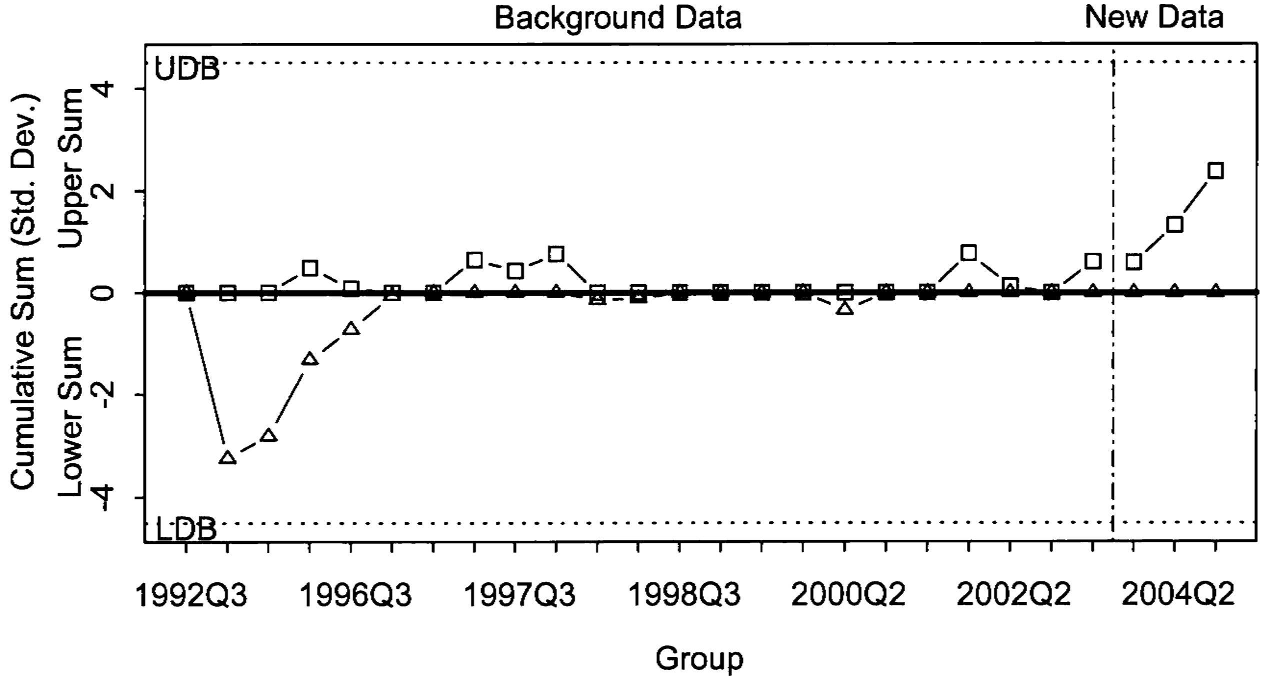
GEOMEGA

5/18/05

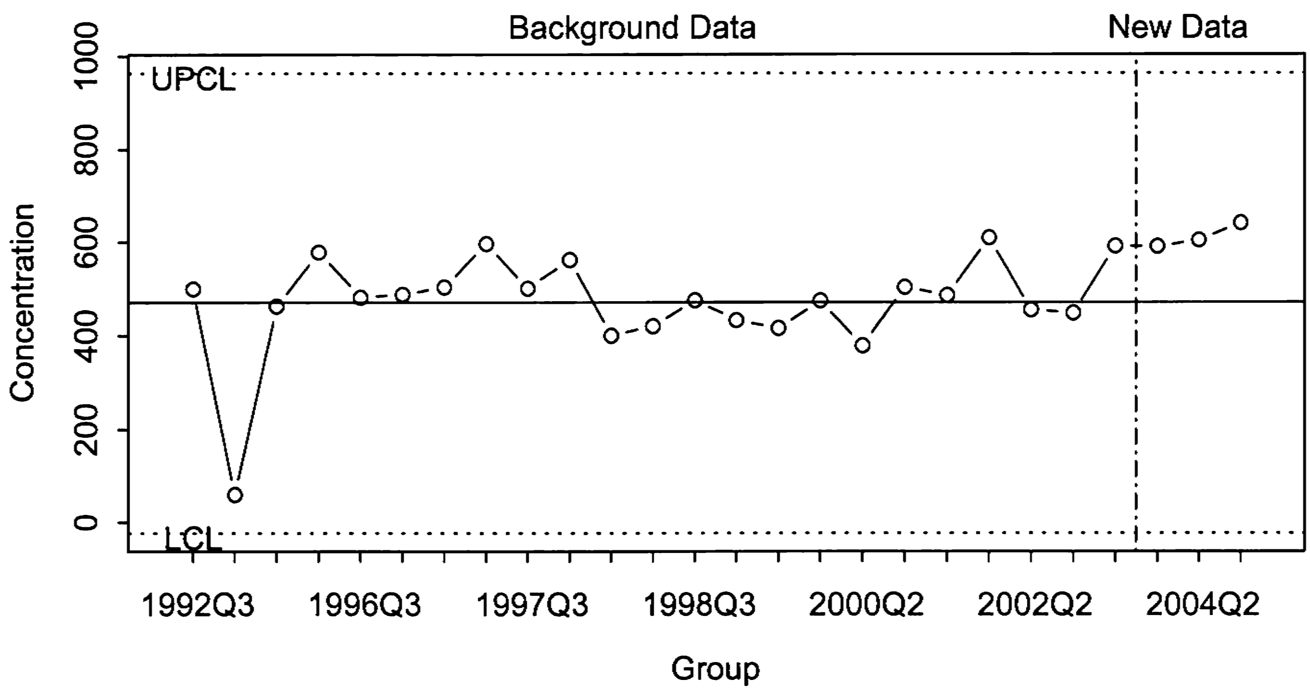
C03302C
Olin-Wilmington

GW-62D
Sodium, Dissolved
mg/l

CUSUM CHART



Shewhart Chart

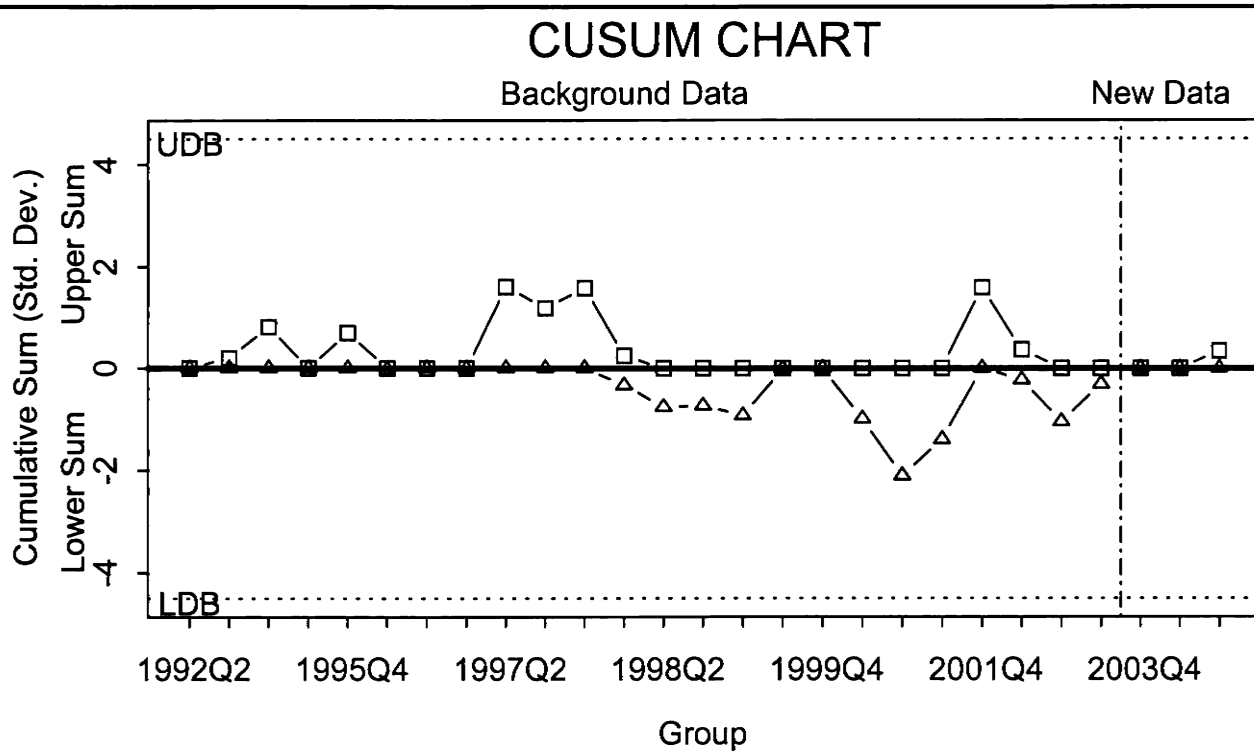


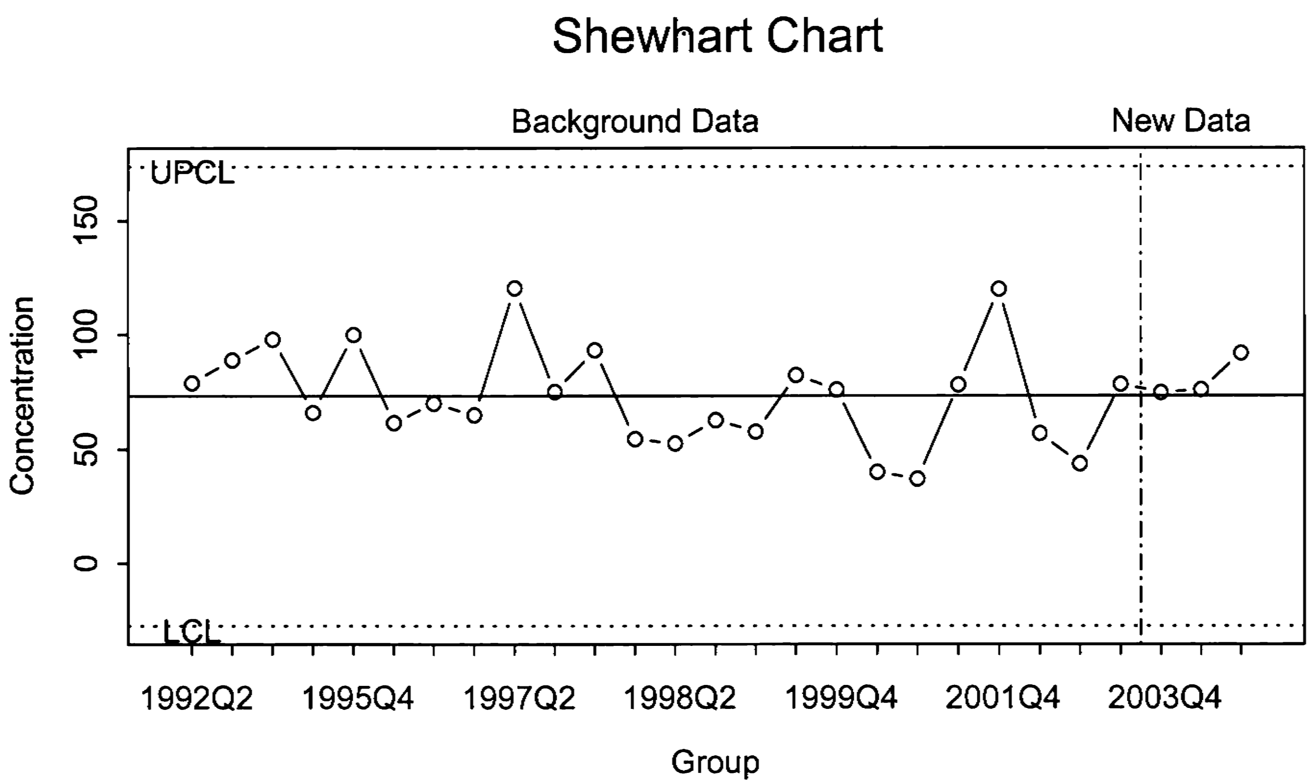
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-62D
Specific Conductance
umhos/cm



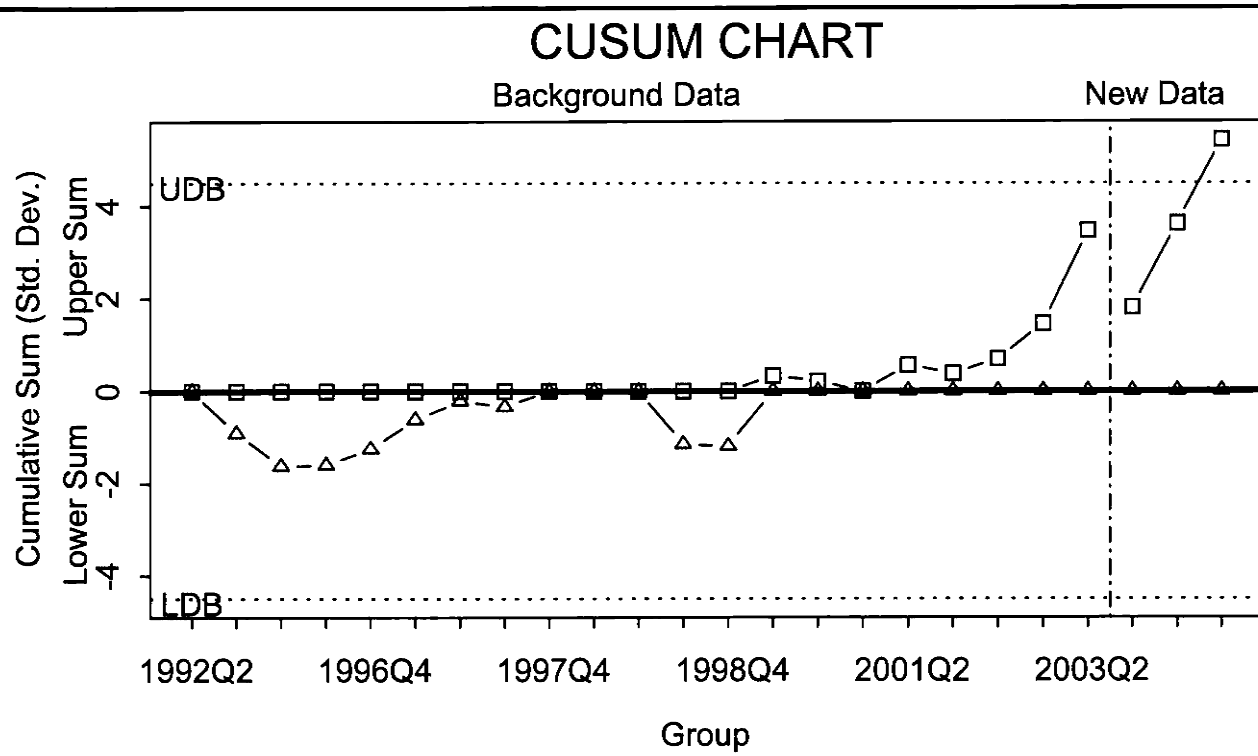


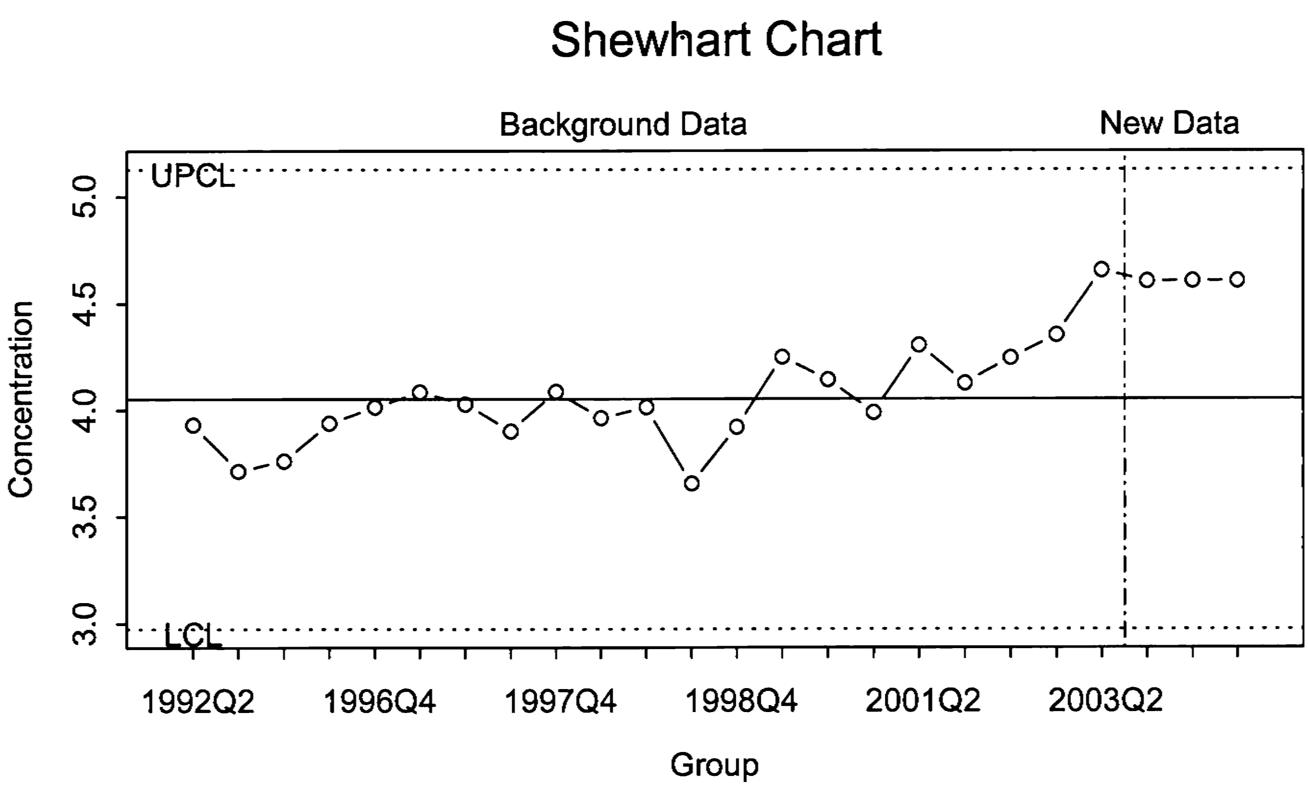
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-62D
Sulfate as SO4
mg/l



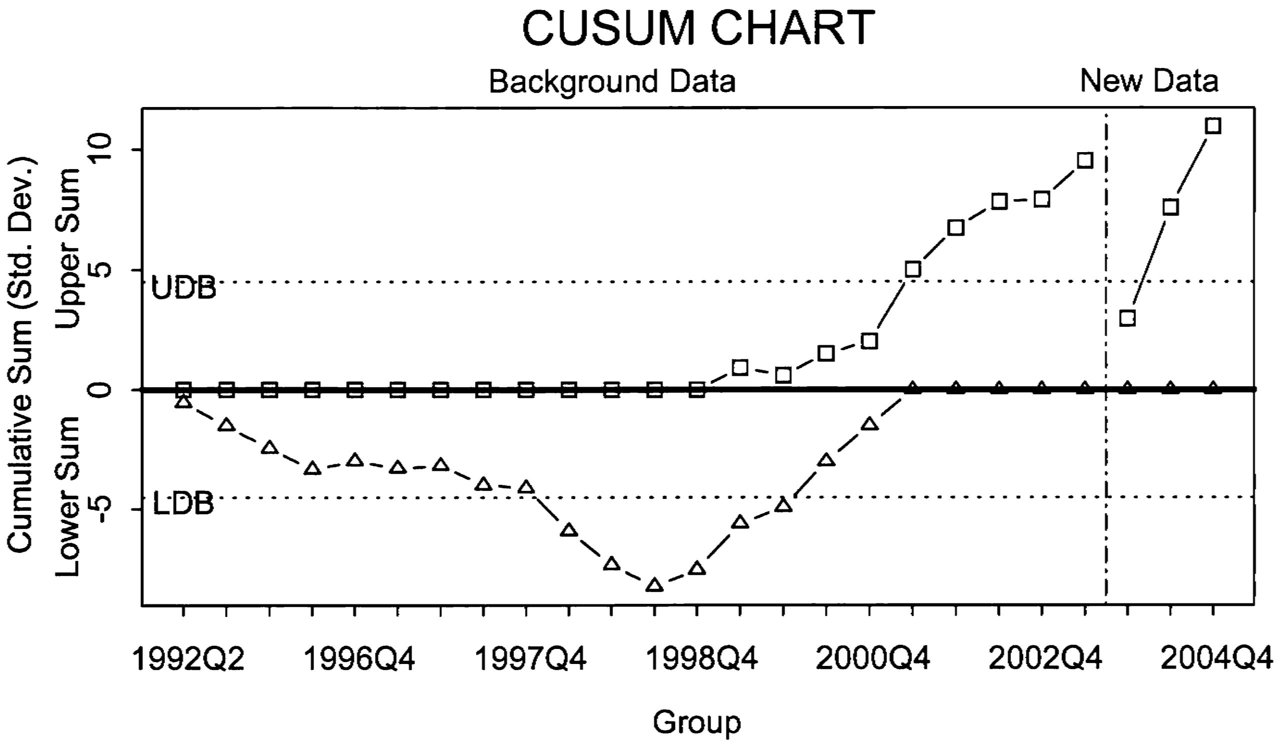


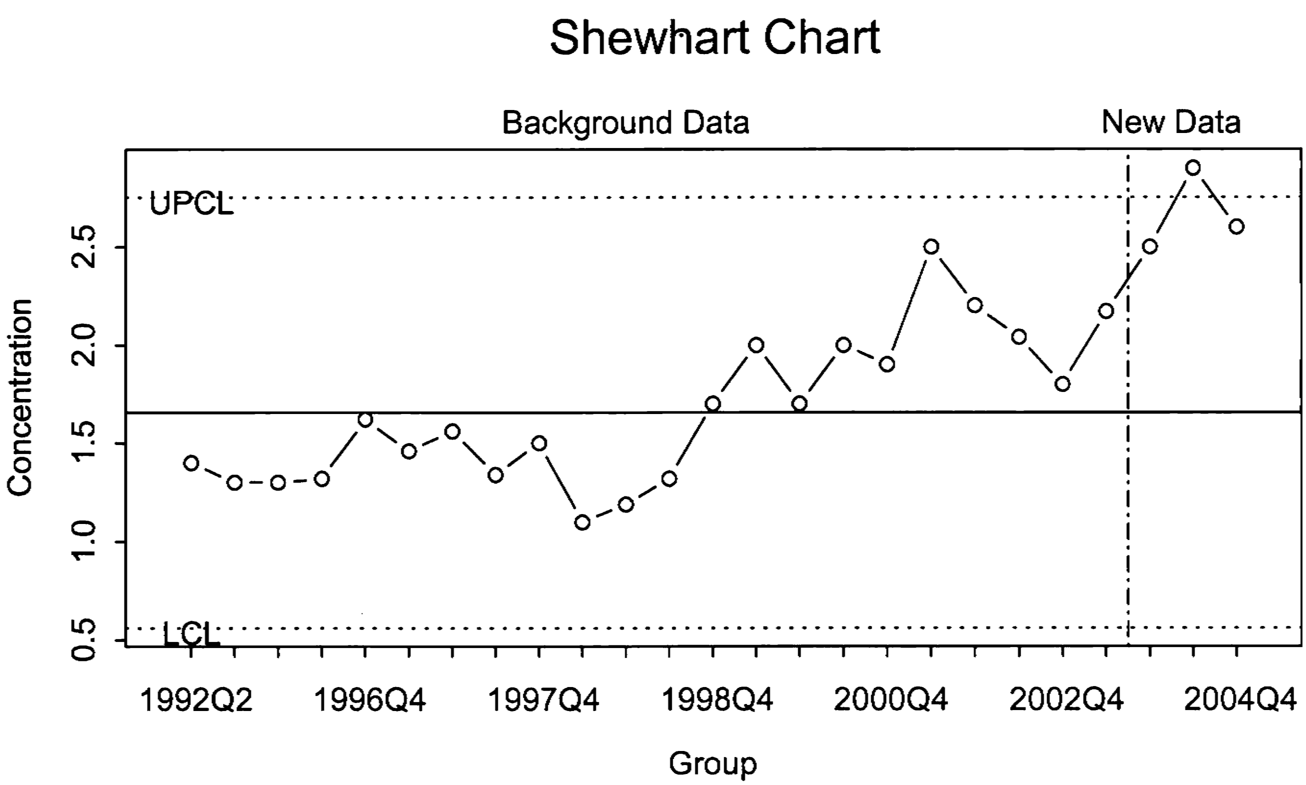
GEOMEGA

5/18/05

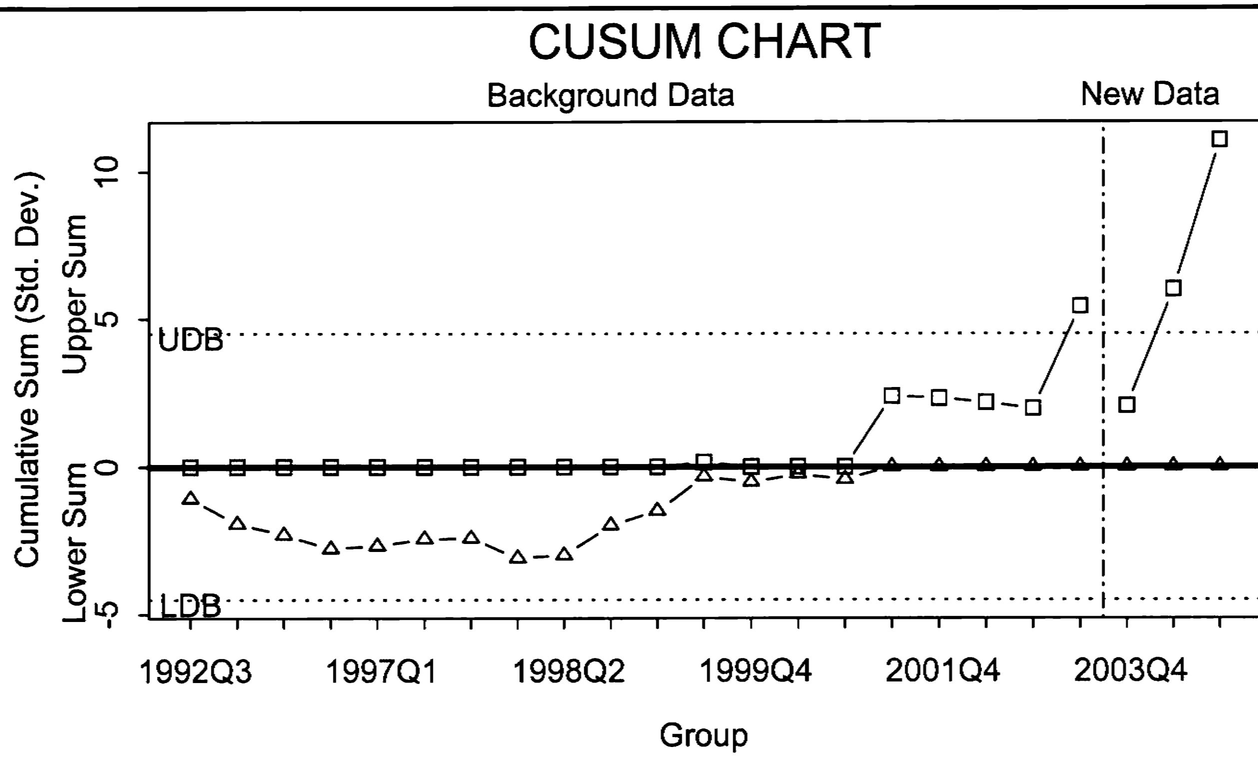
C03302C
Olin-Wilmington

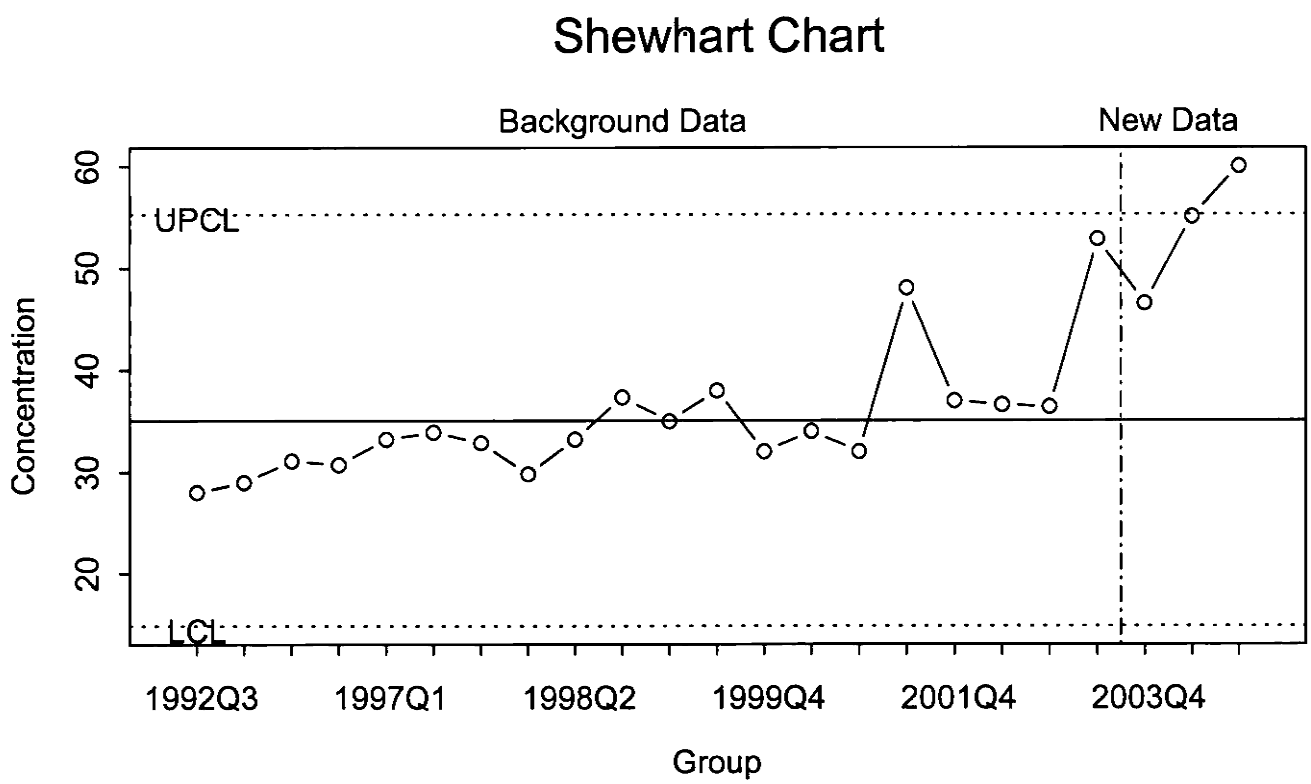
GW-62M
Chloride
Log(mg/l)





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-62M Nitrogen, Ammonia mg/l	





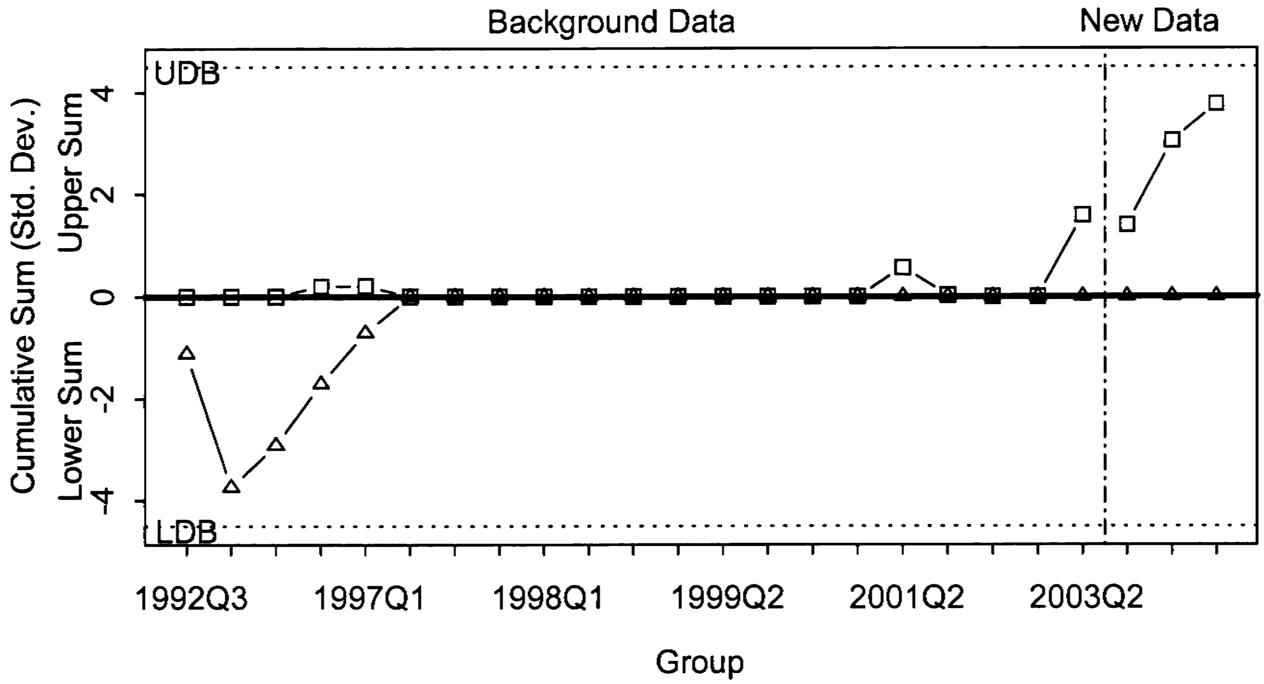
GEOMEGA

5/18/05

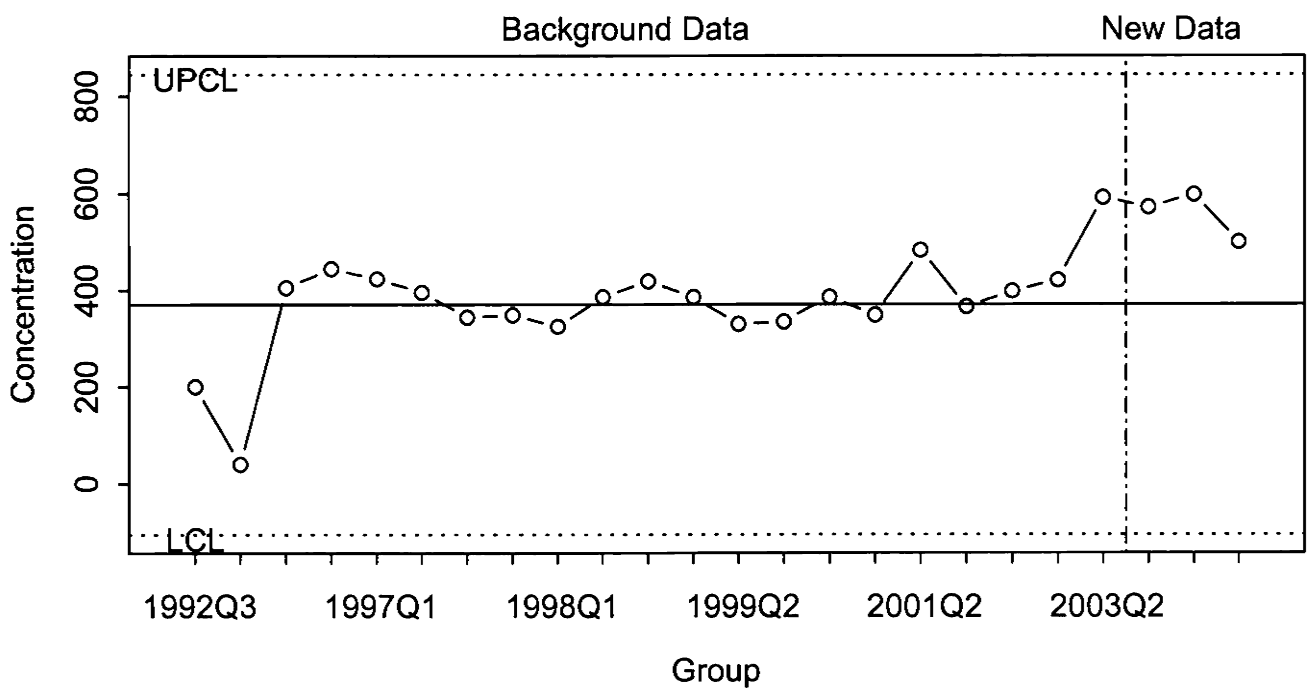
C03302C
Olin-Wilmington

GW-62M
Sodium, Dissolved
mg/l

CUSUM CHART



Shewhart Chart



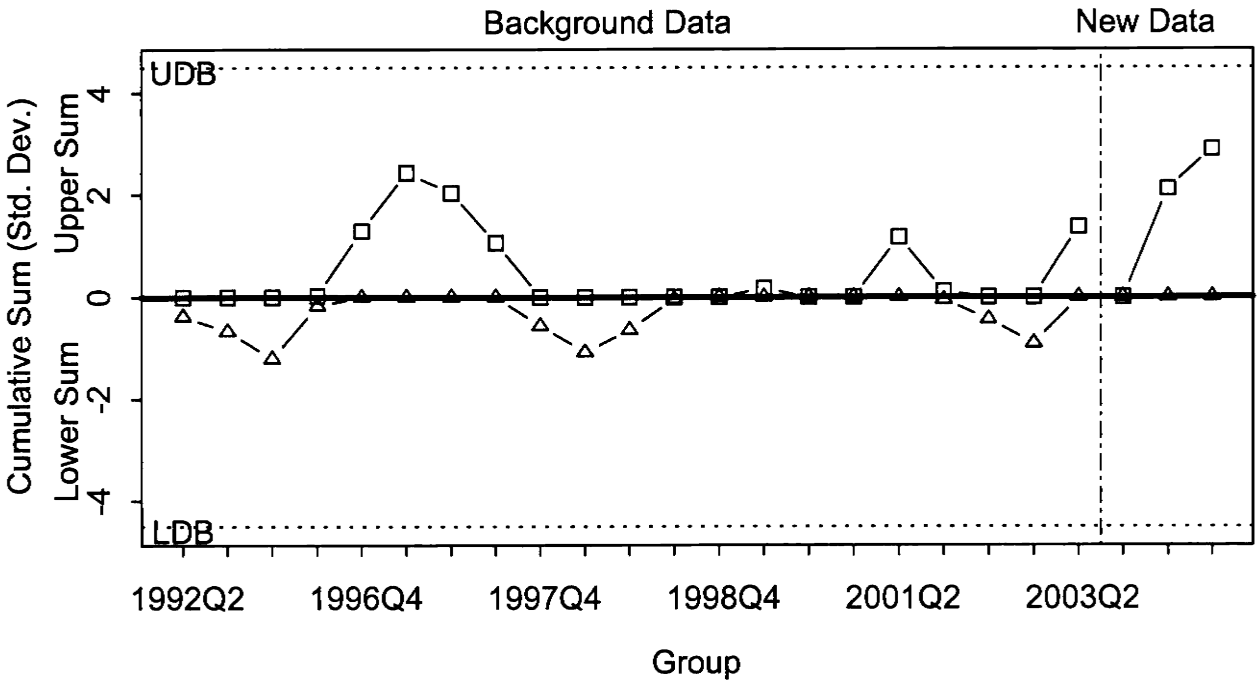
GEOMEGA

5/18/05

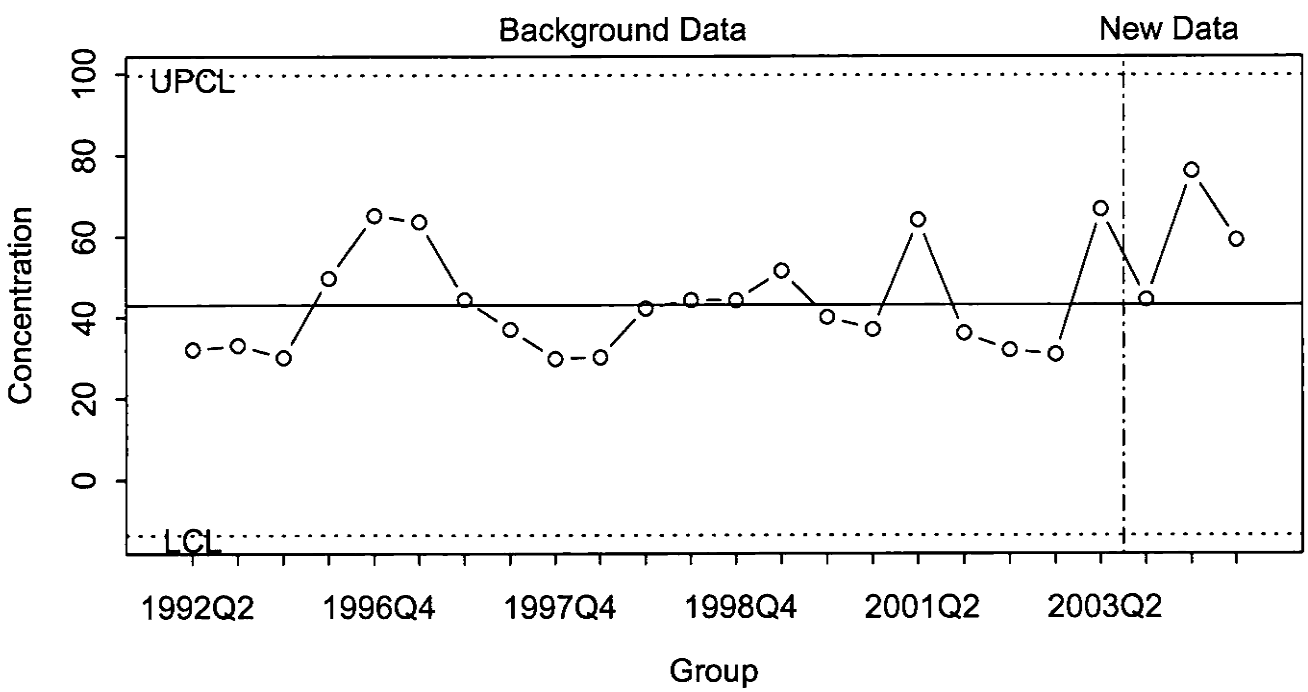
C03302C
Olin-Wilmington

GW-62M
Specific Conductance
umhos/cm

CUSUM CHART



Shewhart Chart



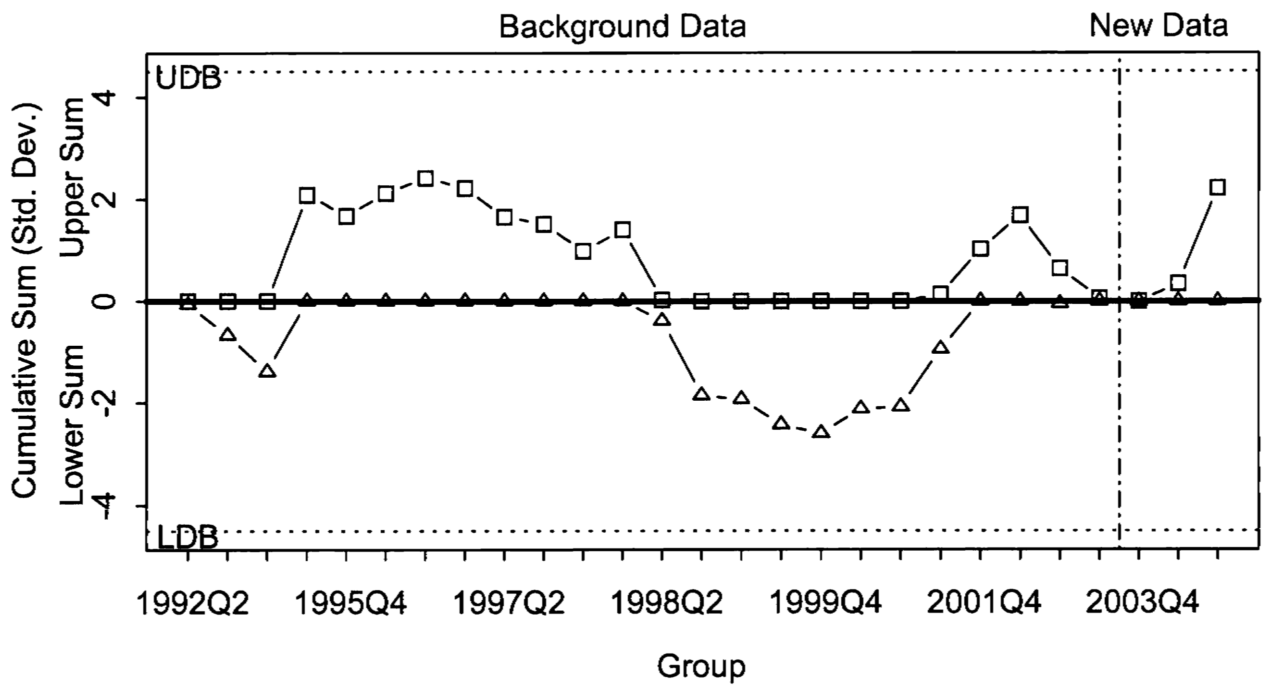
GEOMEGA

5/18/05

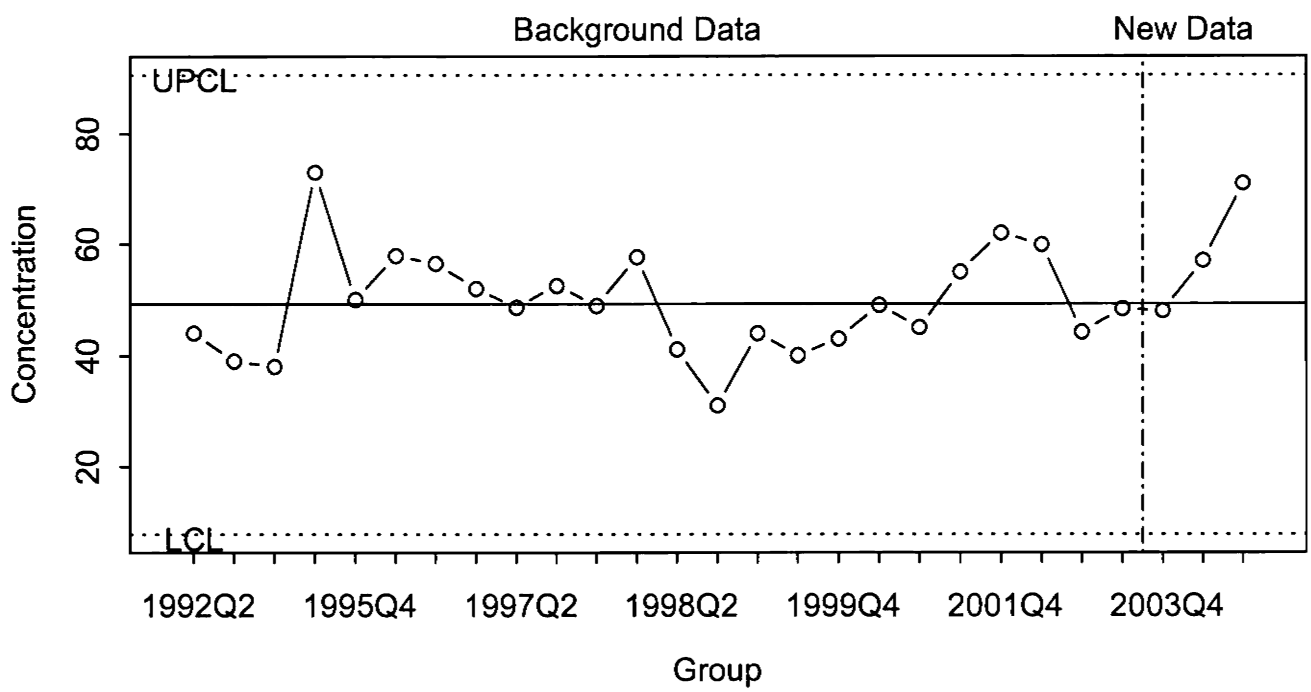
C03302C
Olin-Wilmington

GW-62M
Sulfate as SO4
mg/l

CUSUM CHART



Shewhart Chart

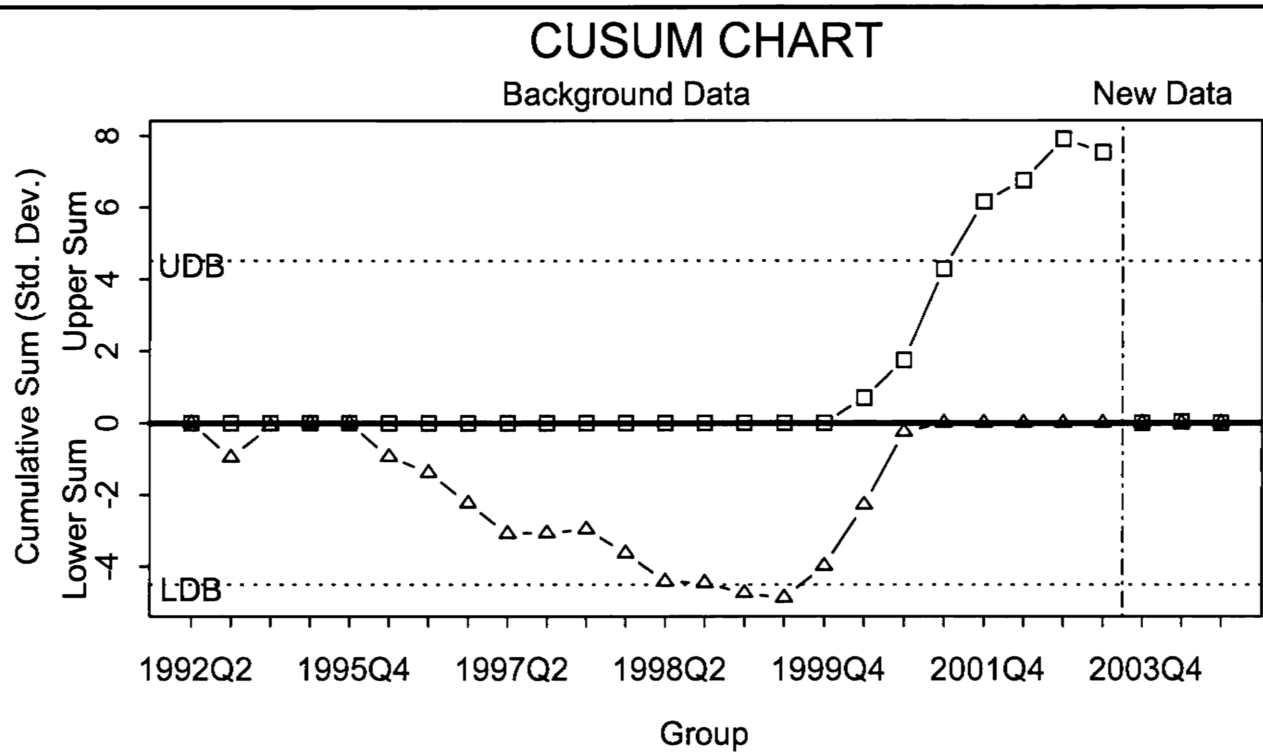


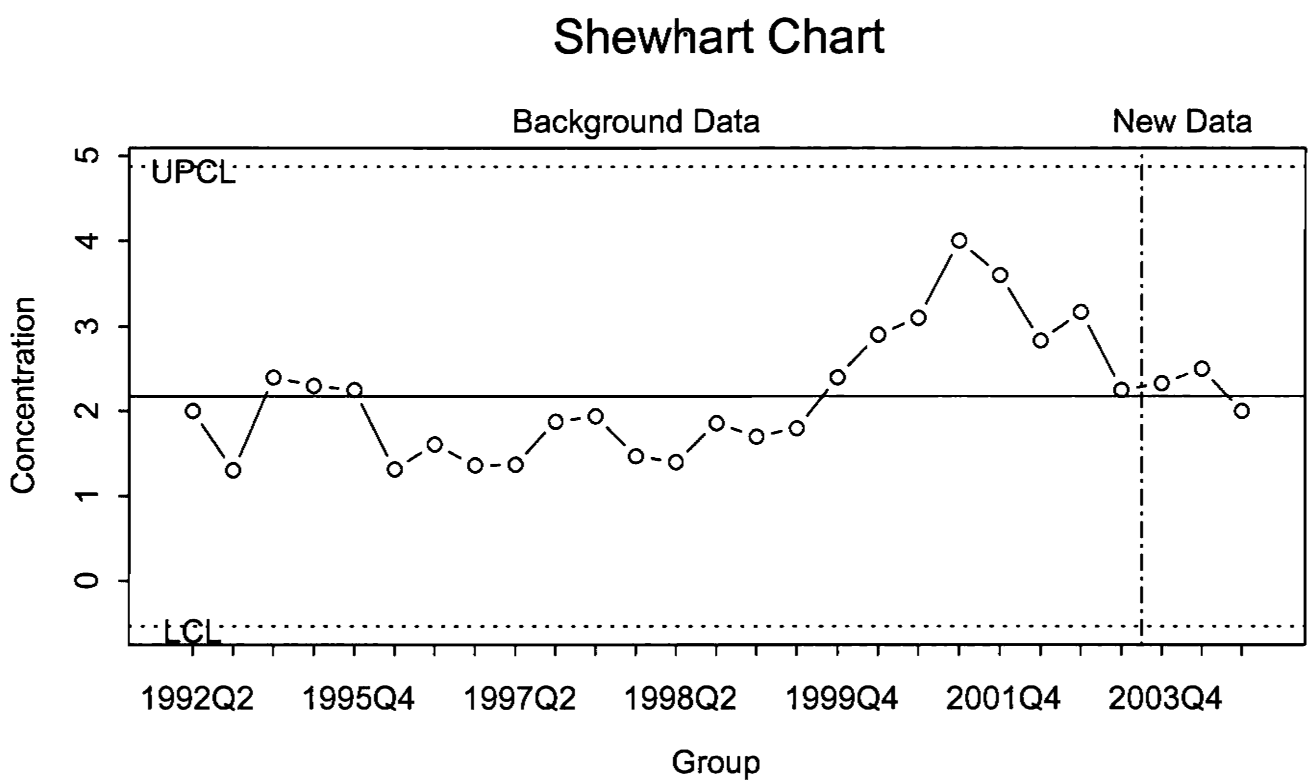
GEOMEGA

5/18/05

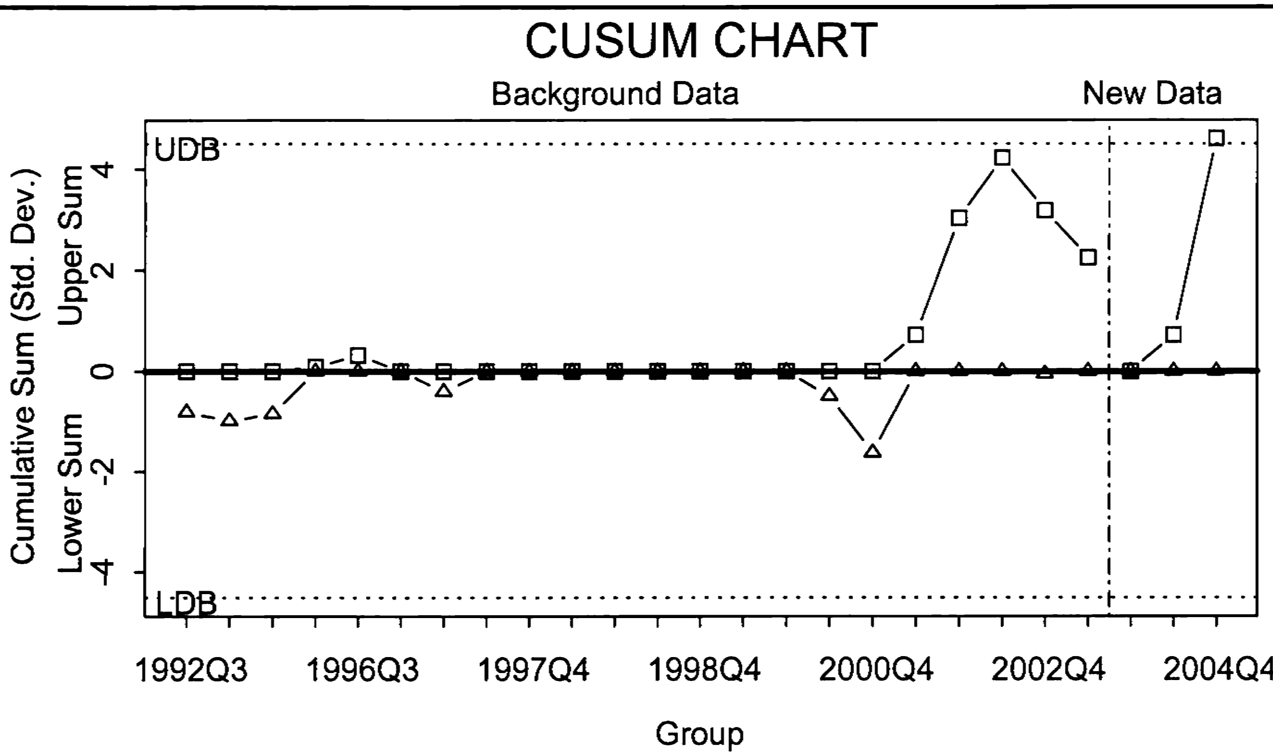
C03302C
Olin-Wilmington

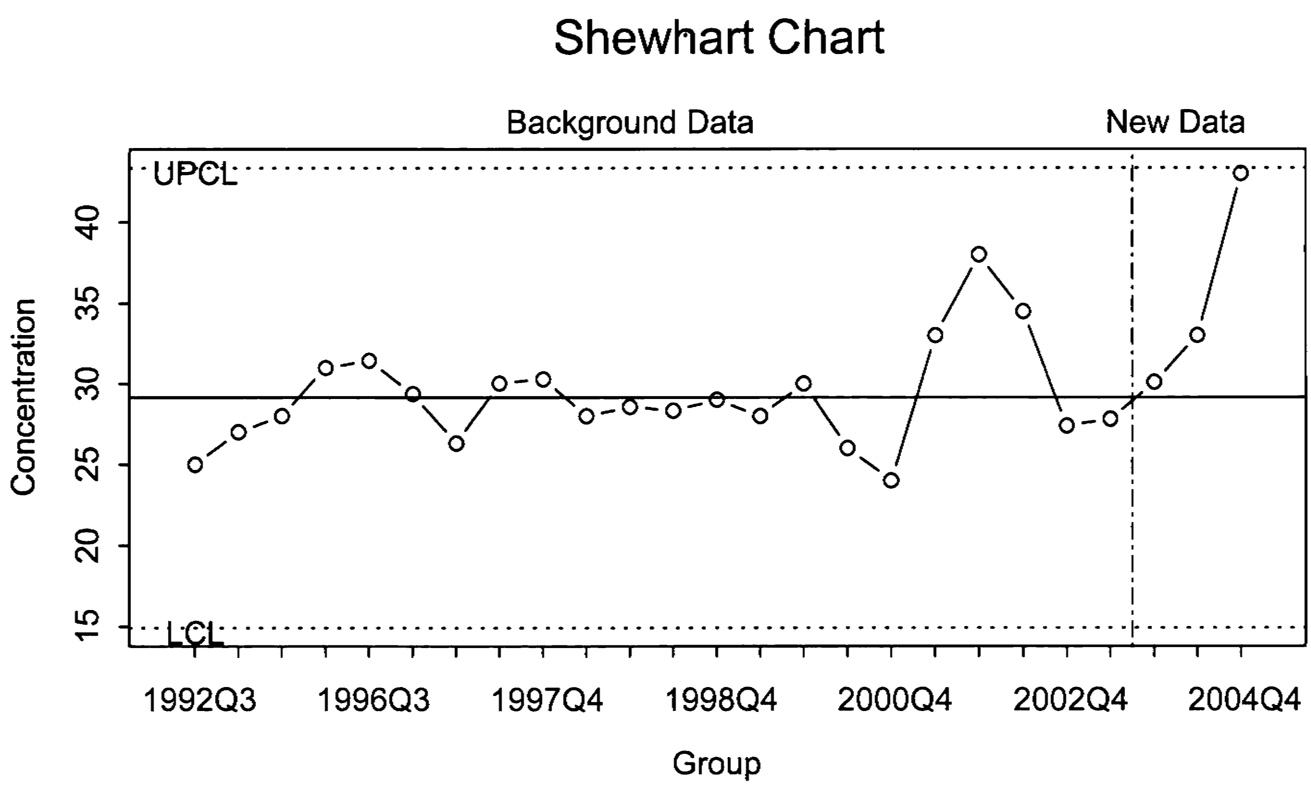
GW-62S
Chloride
mg/l





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-62S Nitrogen, Ammonia mg/l	



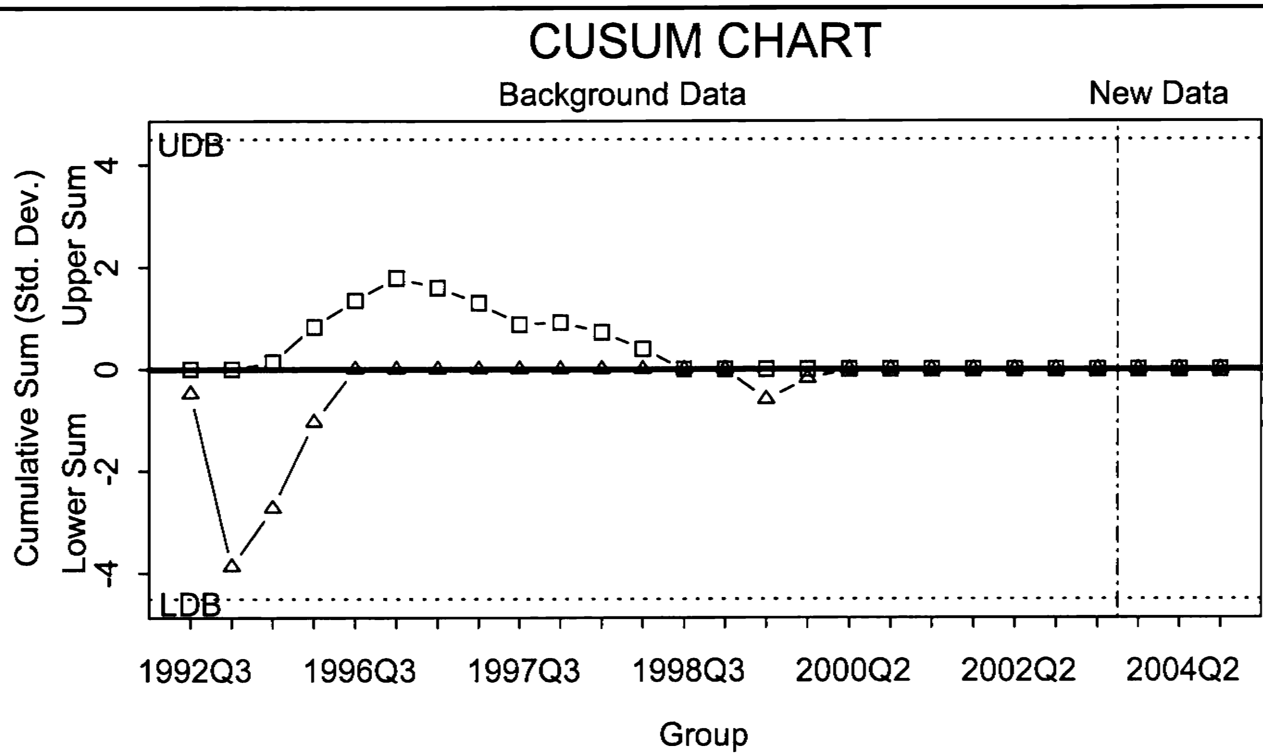


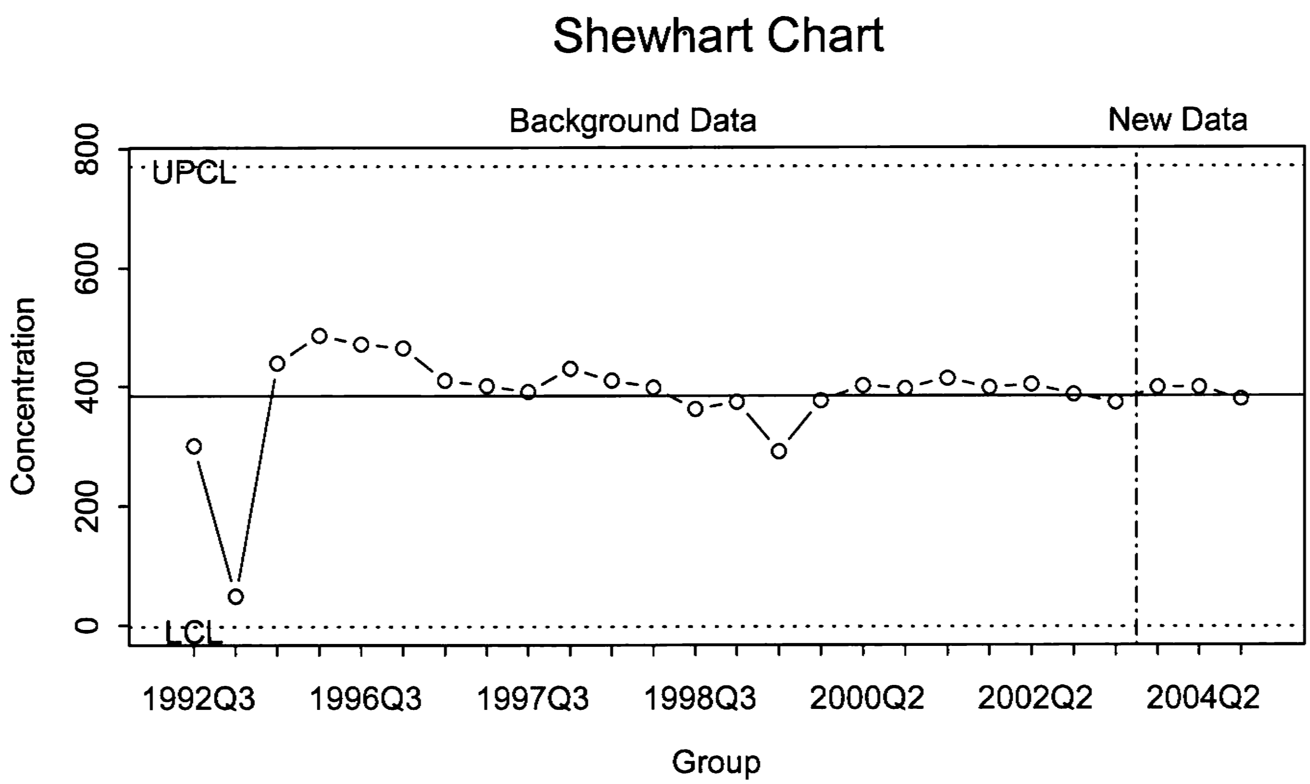
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-62S
Sodium, Dissolved
mg/l



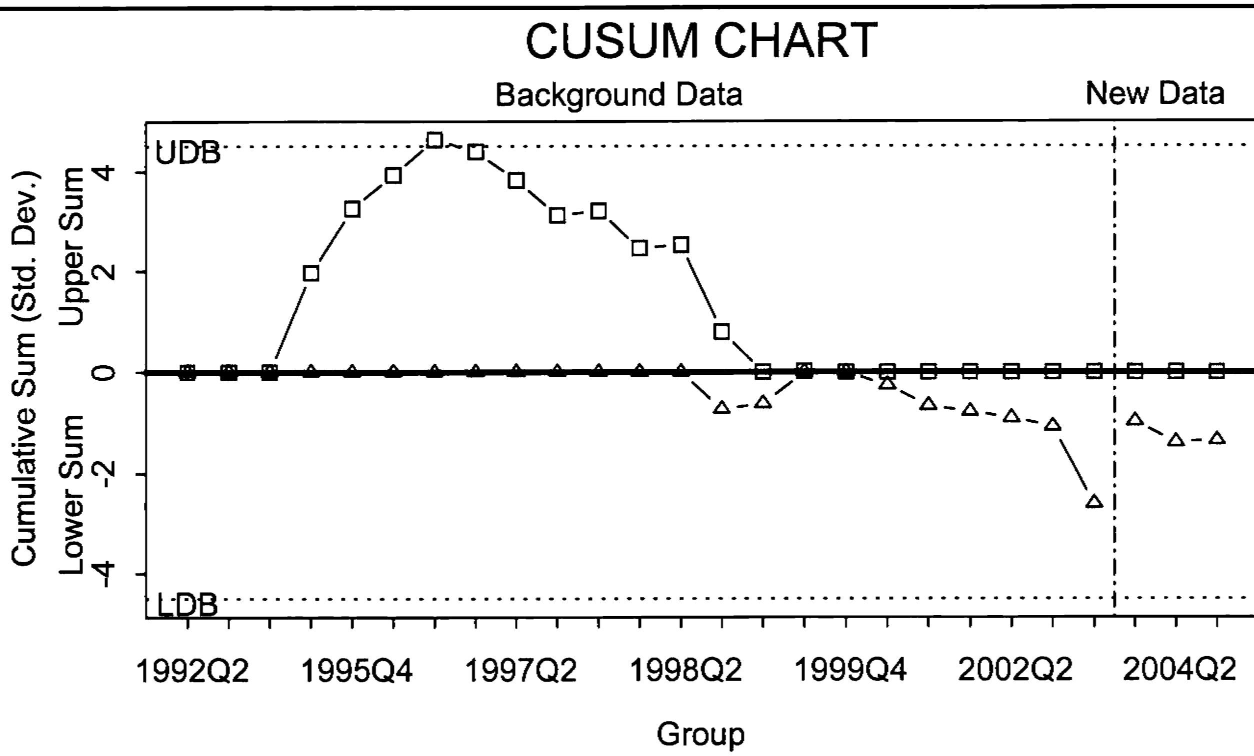


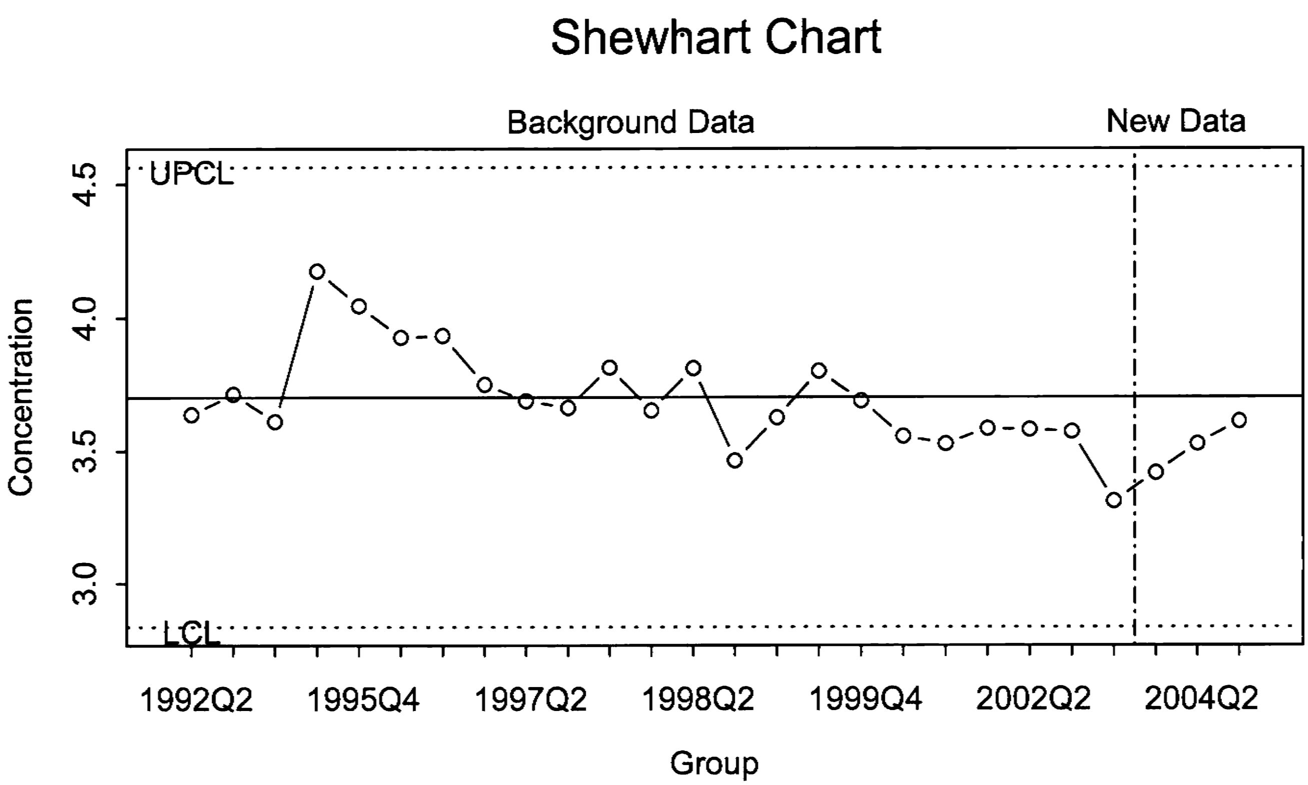
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-62S
Specific Conductance
umhos/cm



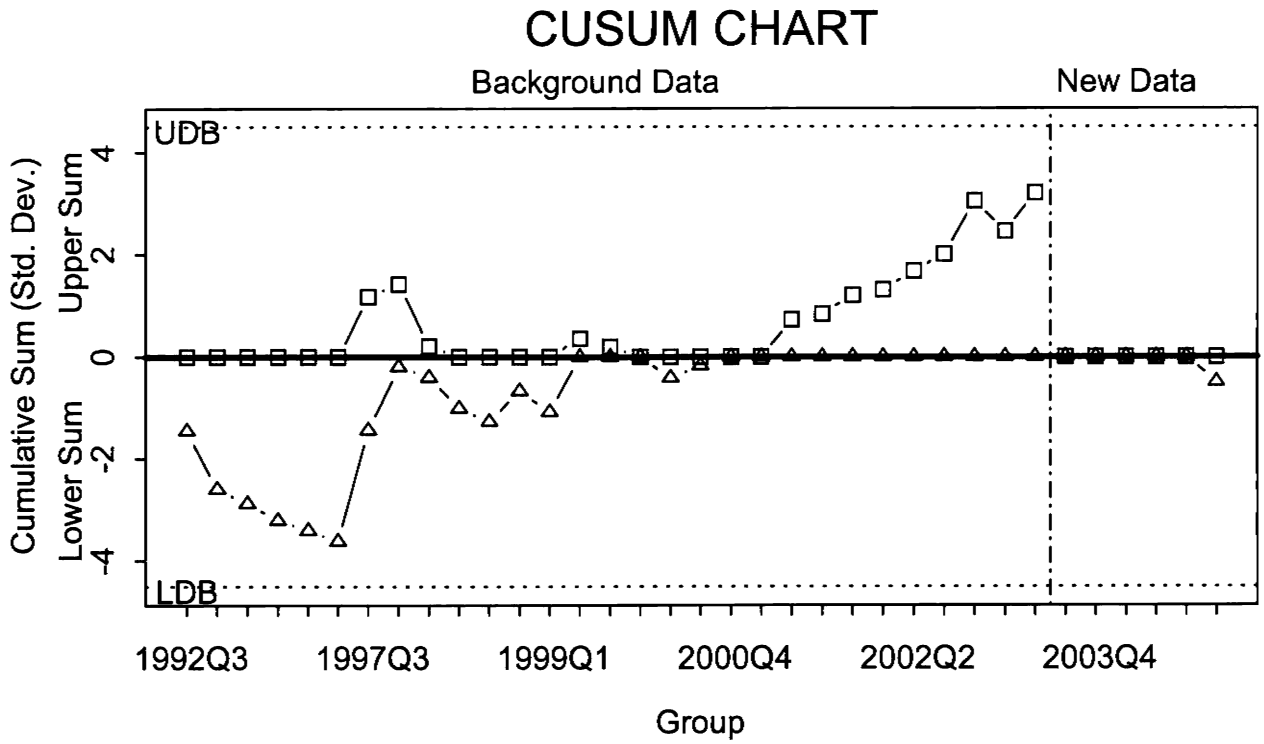


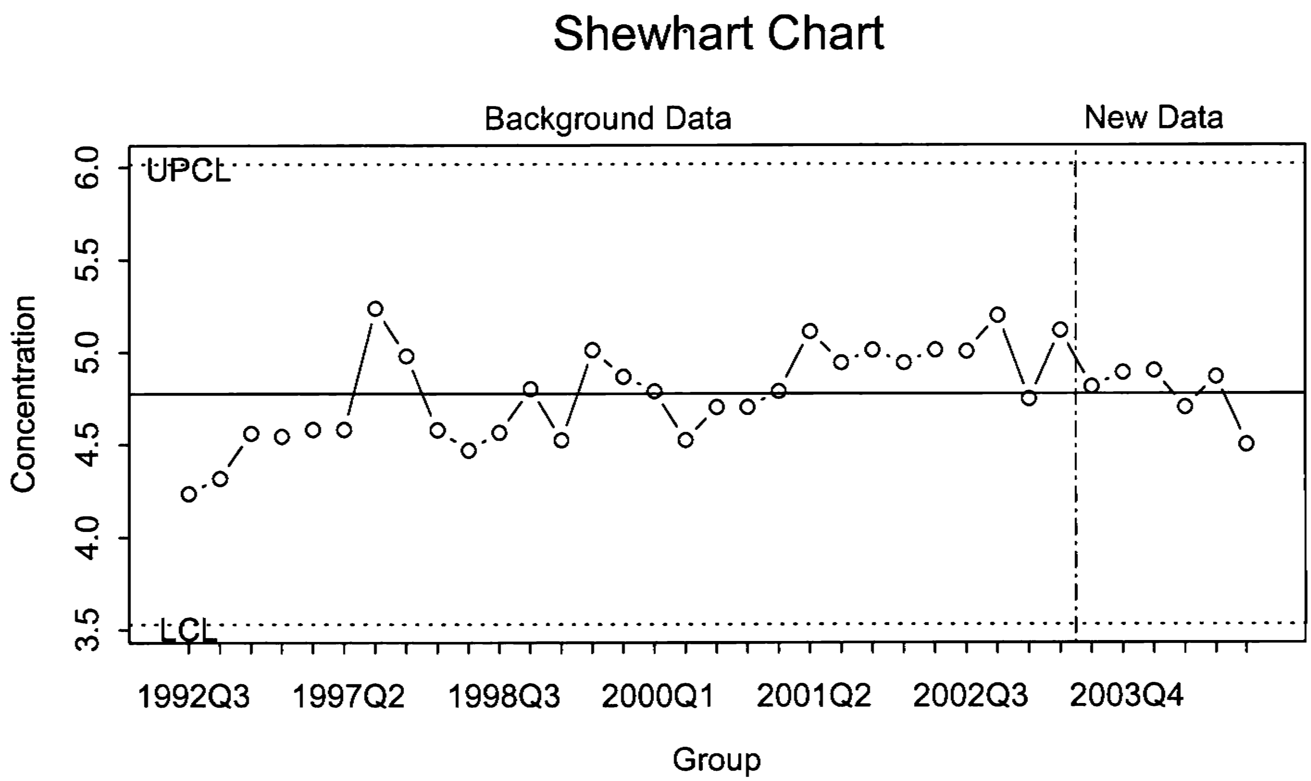
GEOMEGA

5/18/05

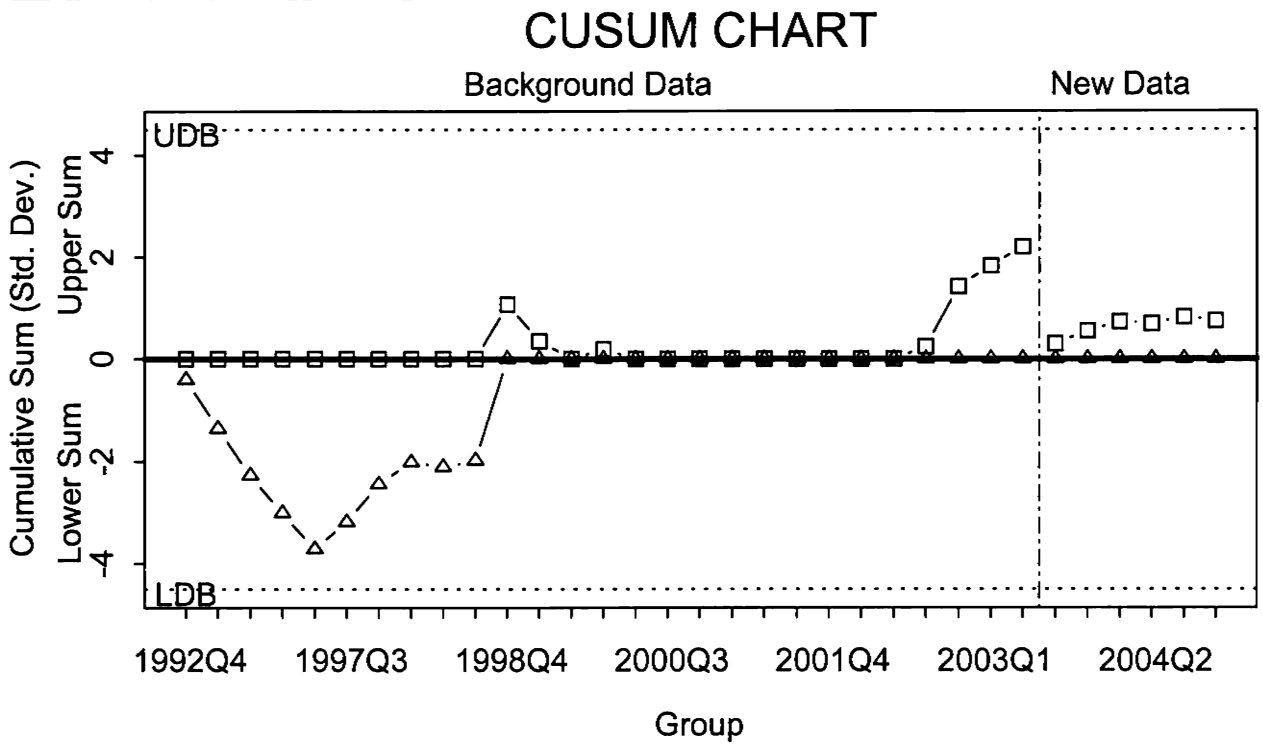
C03302C
Olin-Wilmington

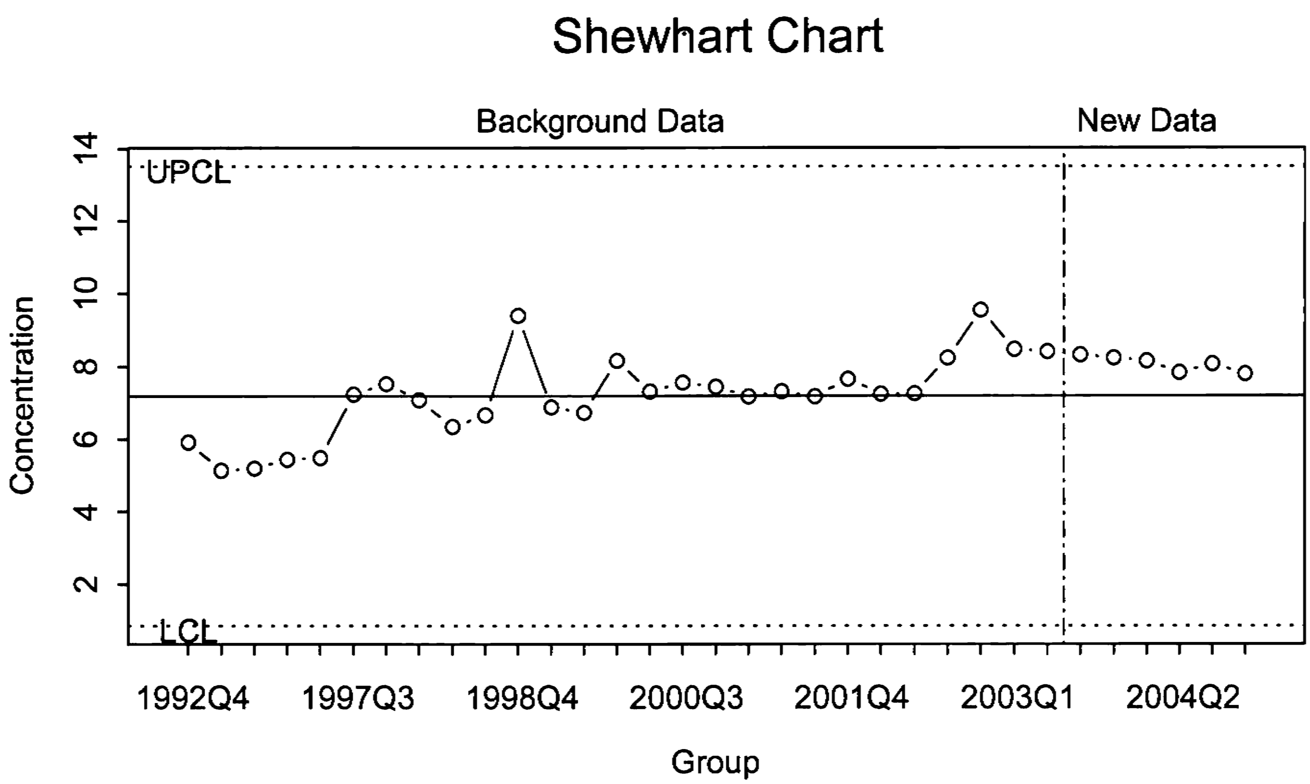
GW-62S
Sulfate as SO4
Log(mg/l)



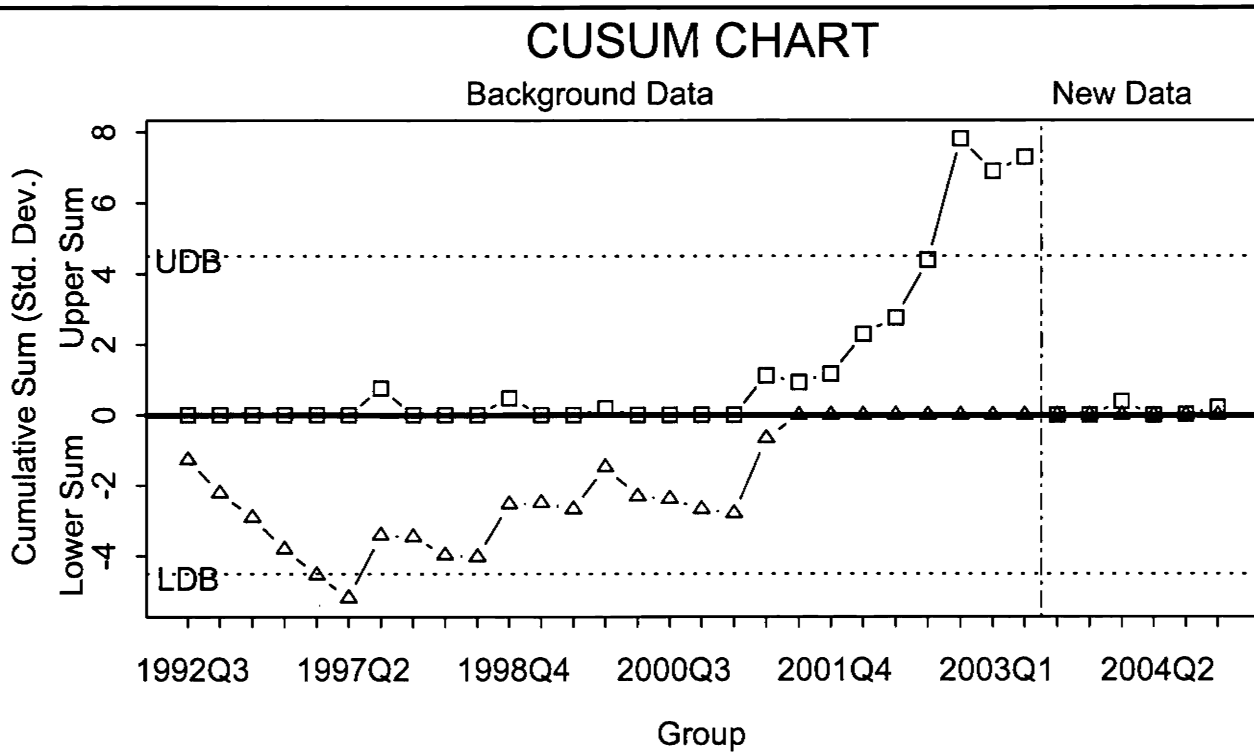


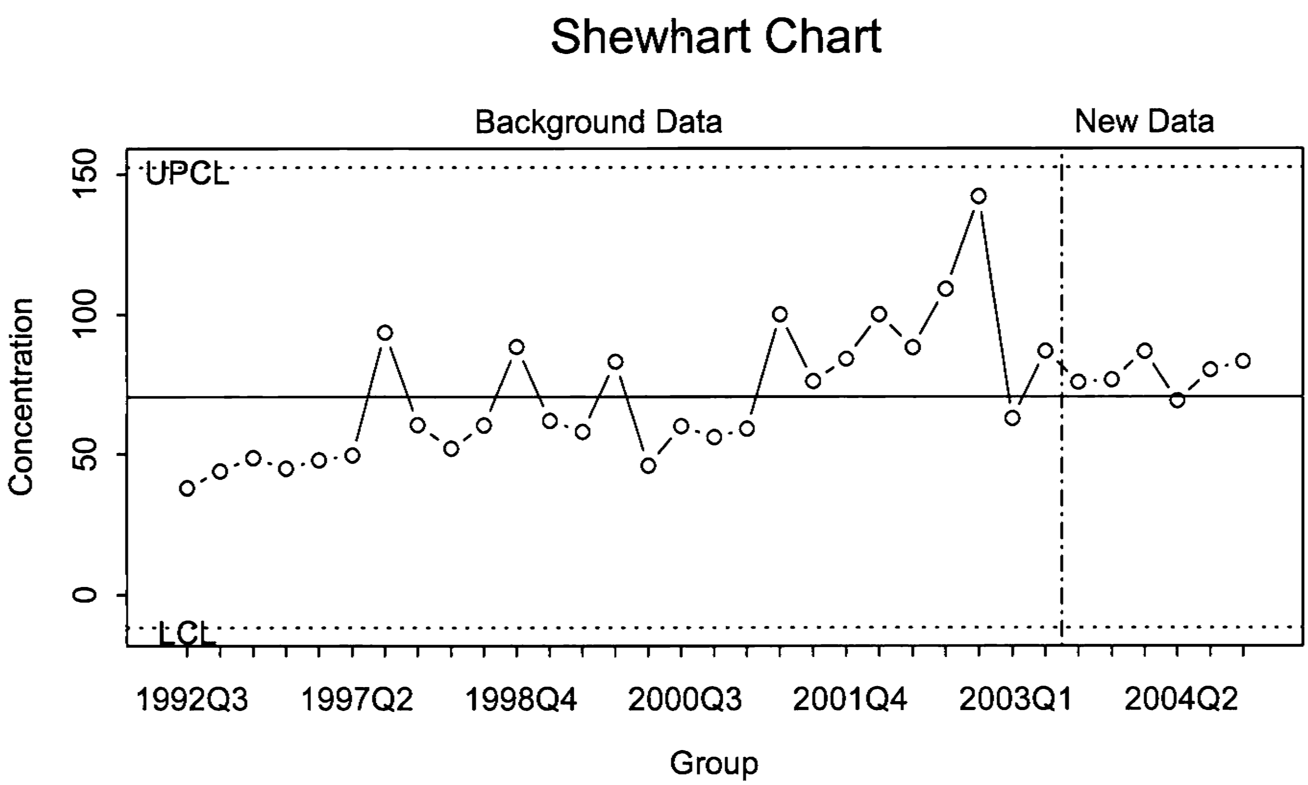
GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-63D Chloride Log(mg/l)	





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-63D Nitrogen, Ammonia Log(ug/l)	



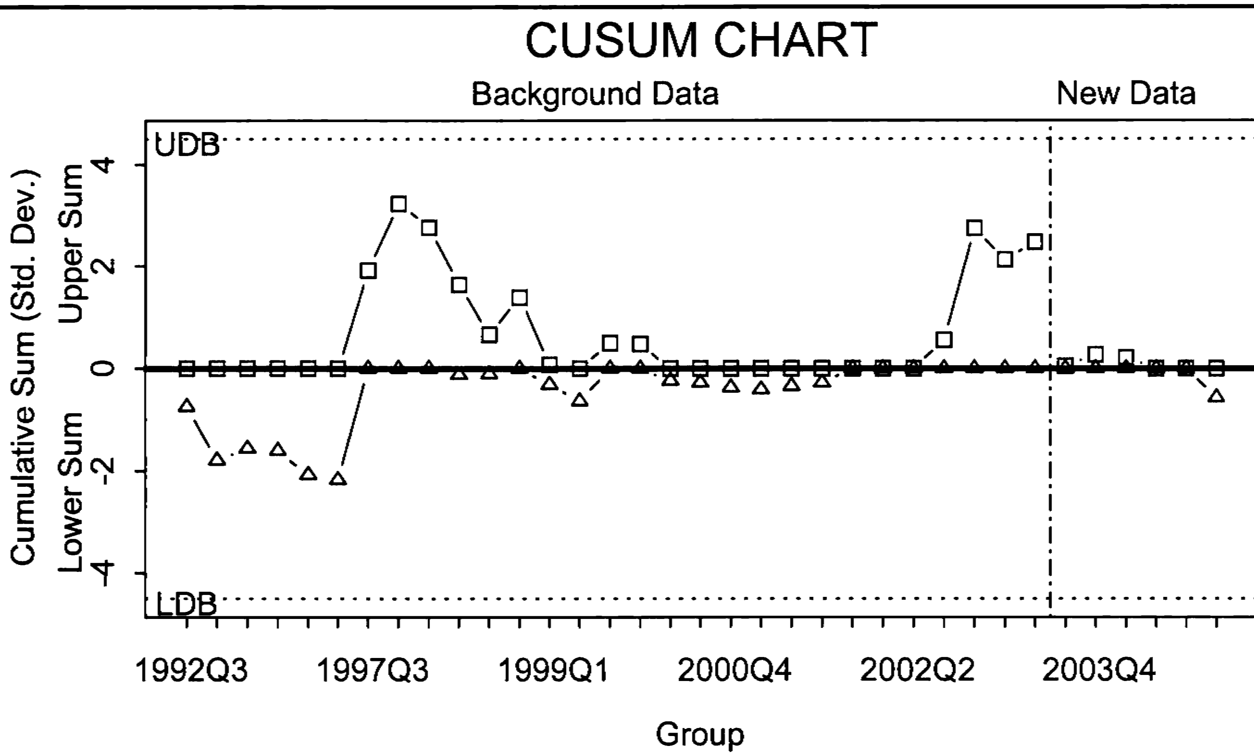


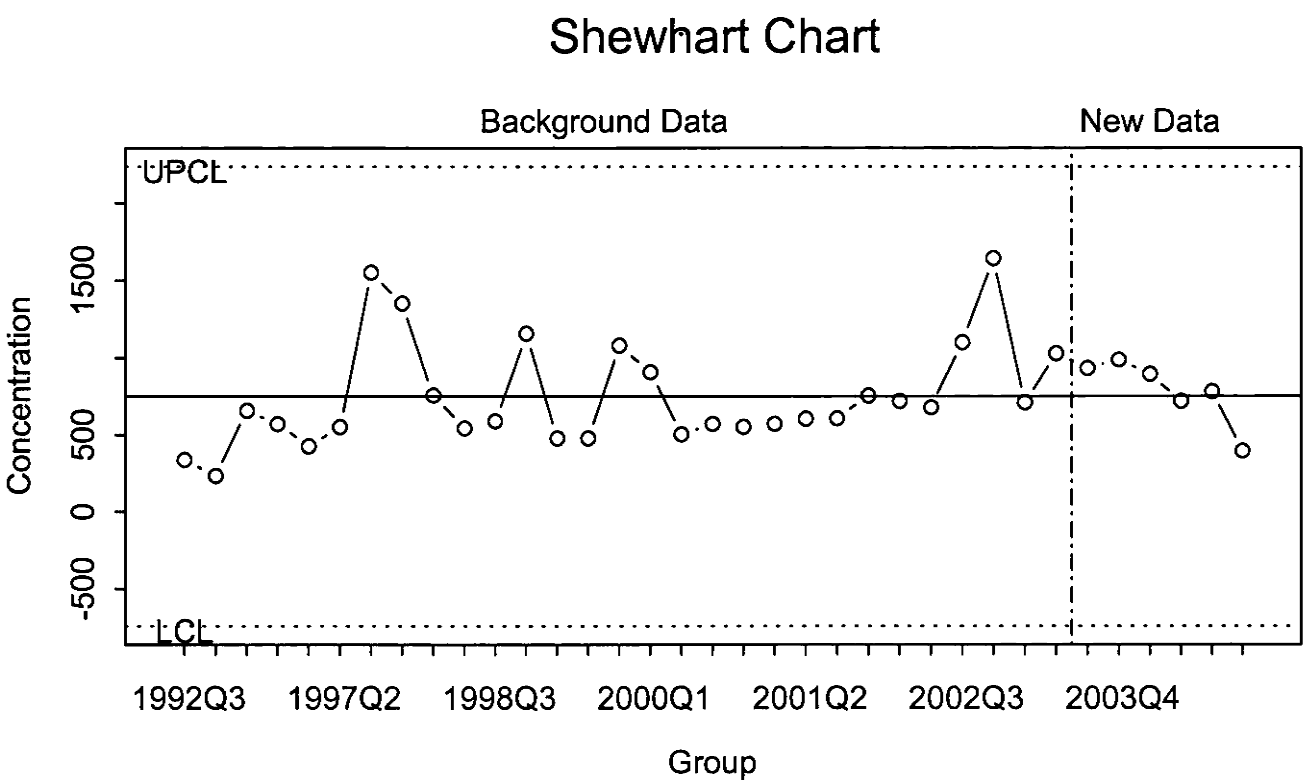
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-63D
Sodium, Dissolved
mg/l



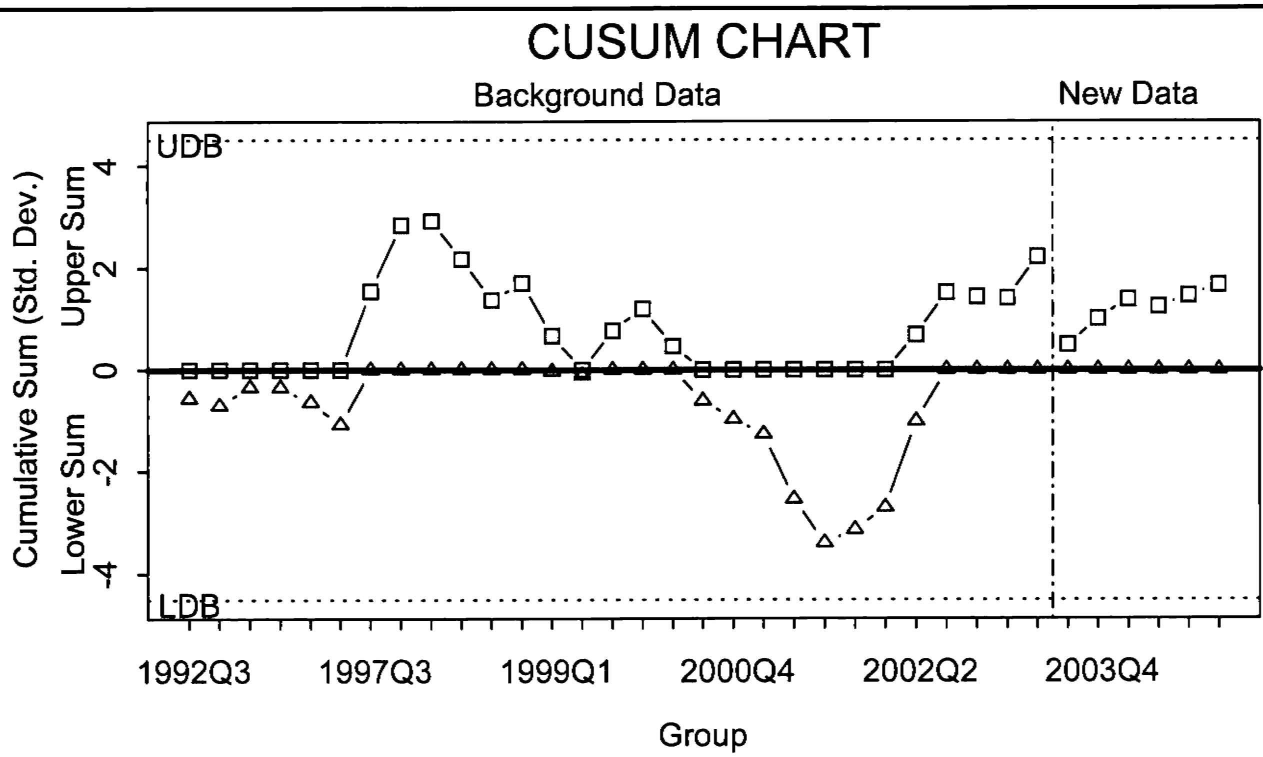


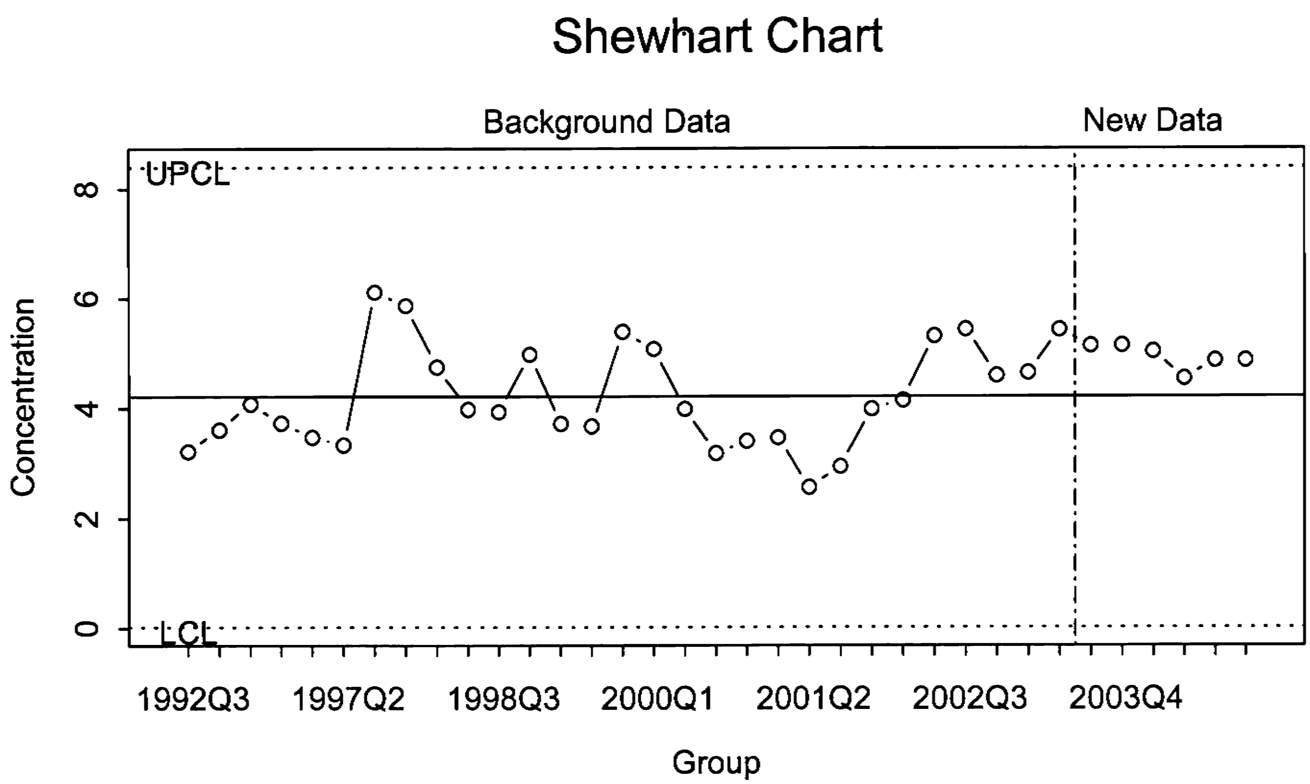
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

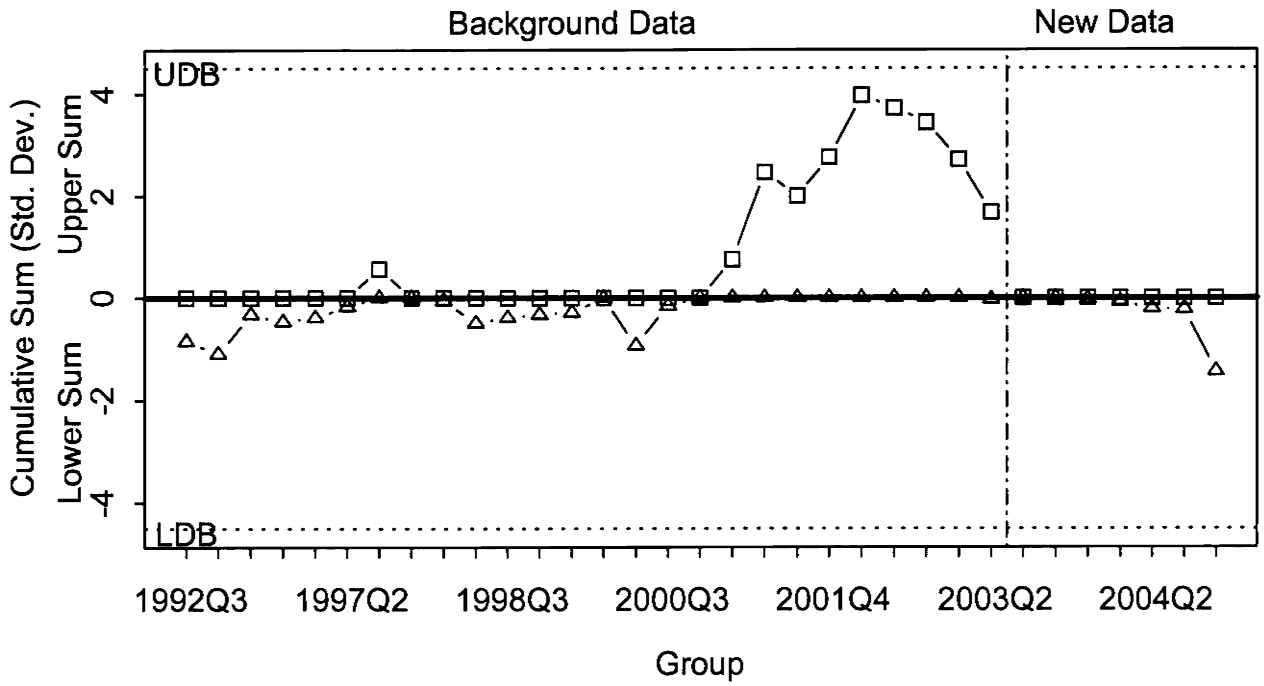
GW-63D
Specific Conductance
umhos/cm



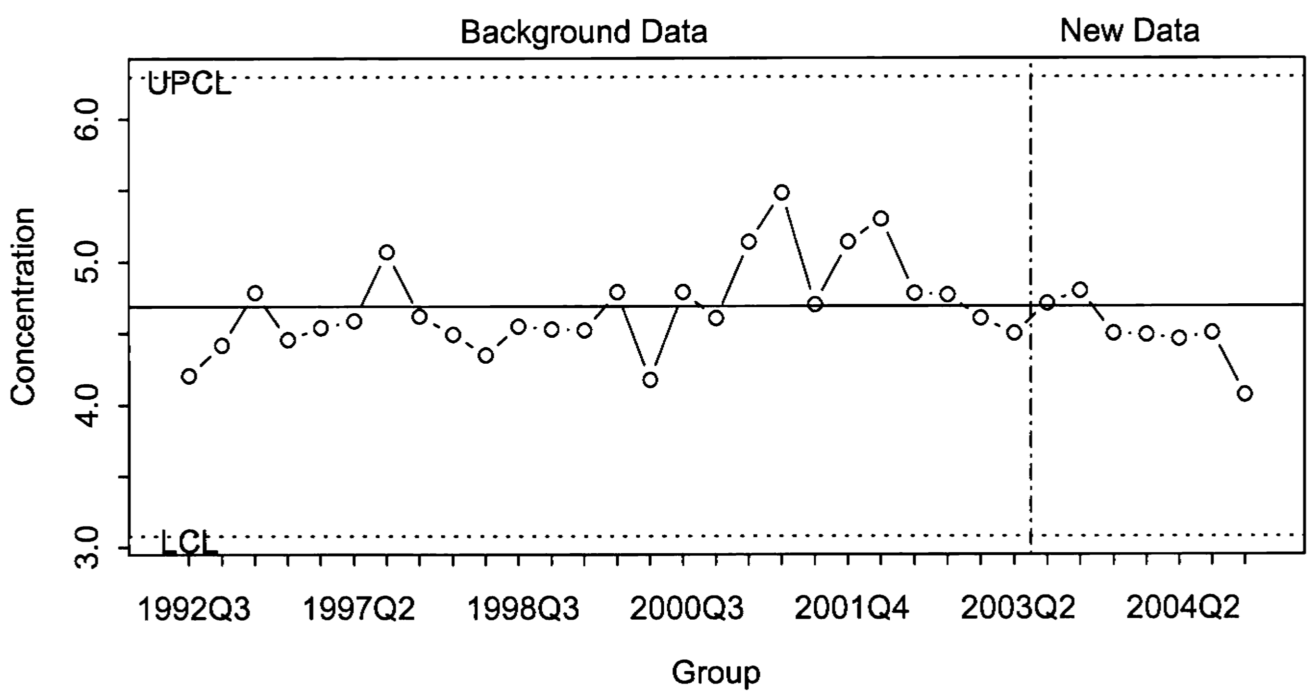


GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-63D Sulfate as SO4 Log(mg/l)	

CUSUM CHART



Shewhart Chart



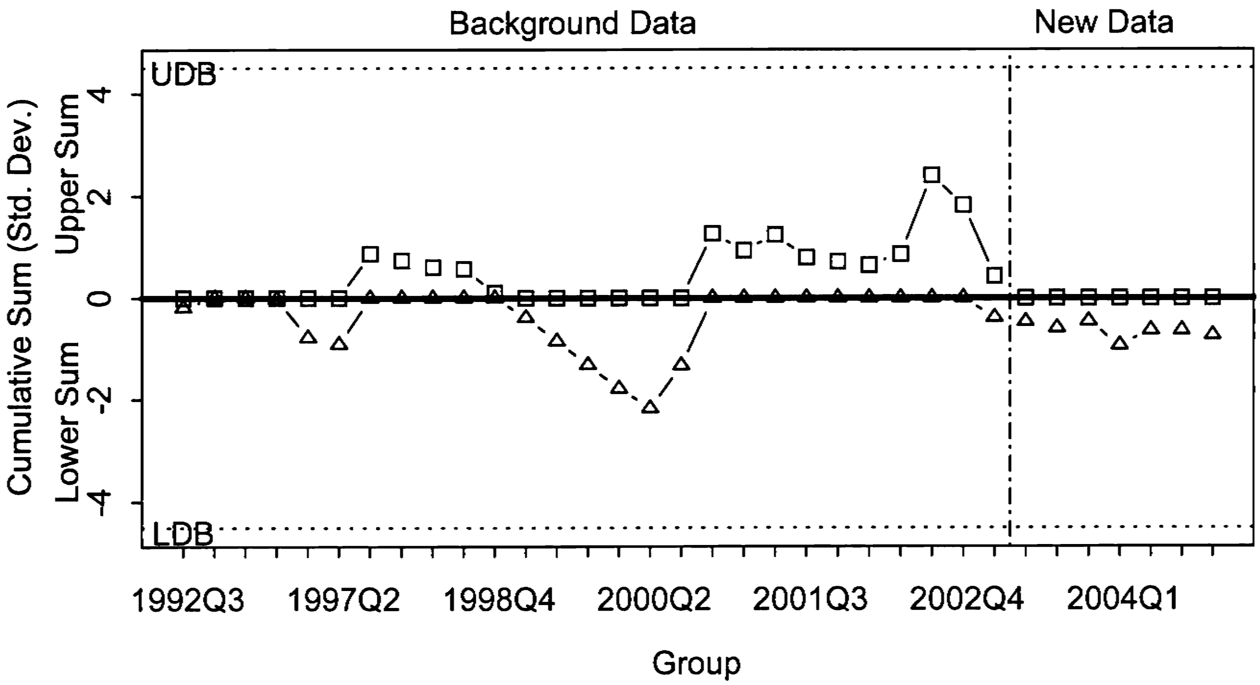
GEOMEGA

5/18/05

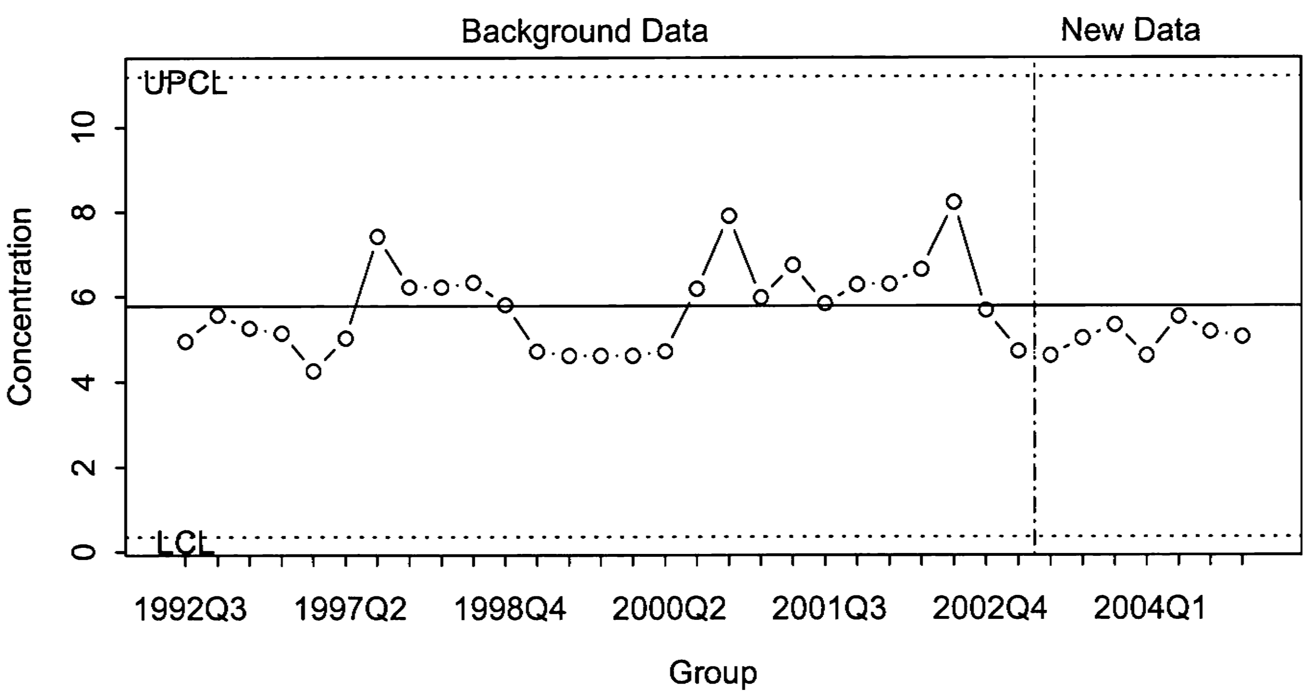
C03302C
Olin-Wilmington

GW-63S
Chloride
Log(mg/l)

CUSUM CHART



Shewhart Chart

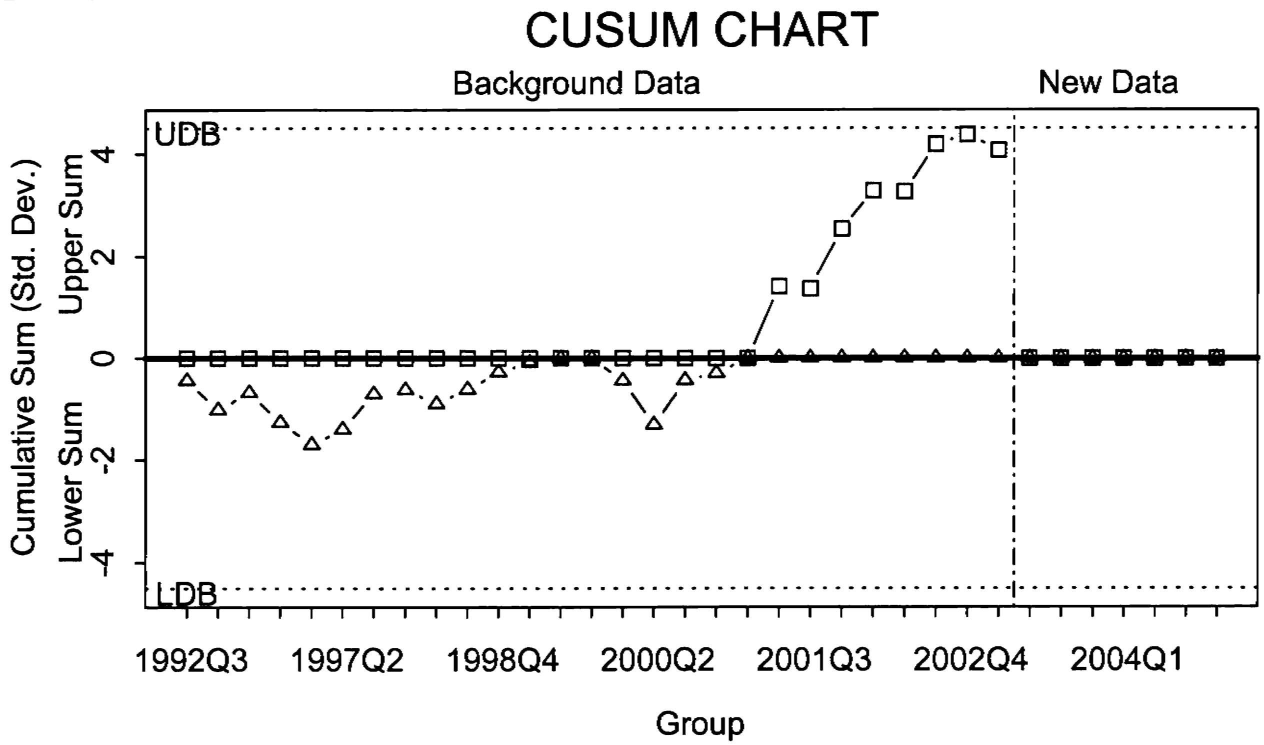


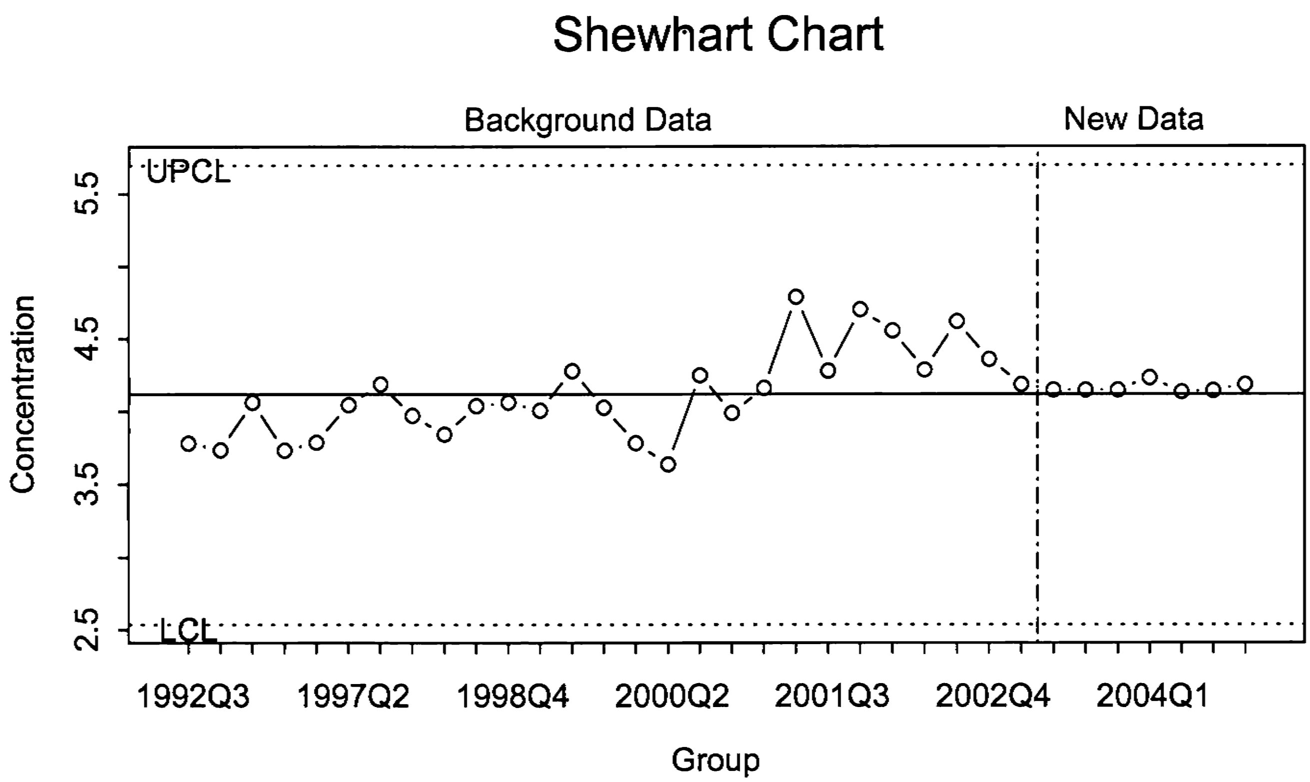
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-63S
Nitrogen, Ammonia
Log(ug/l)



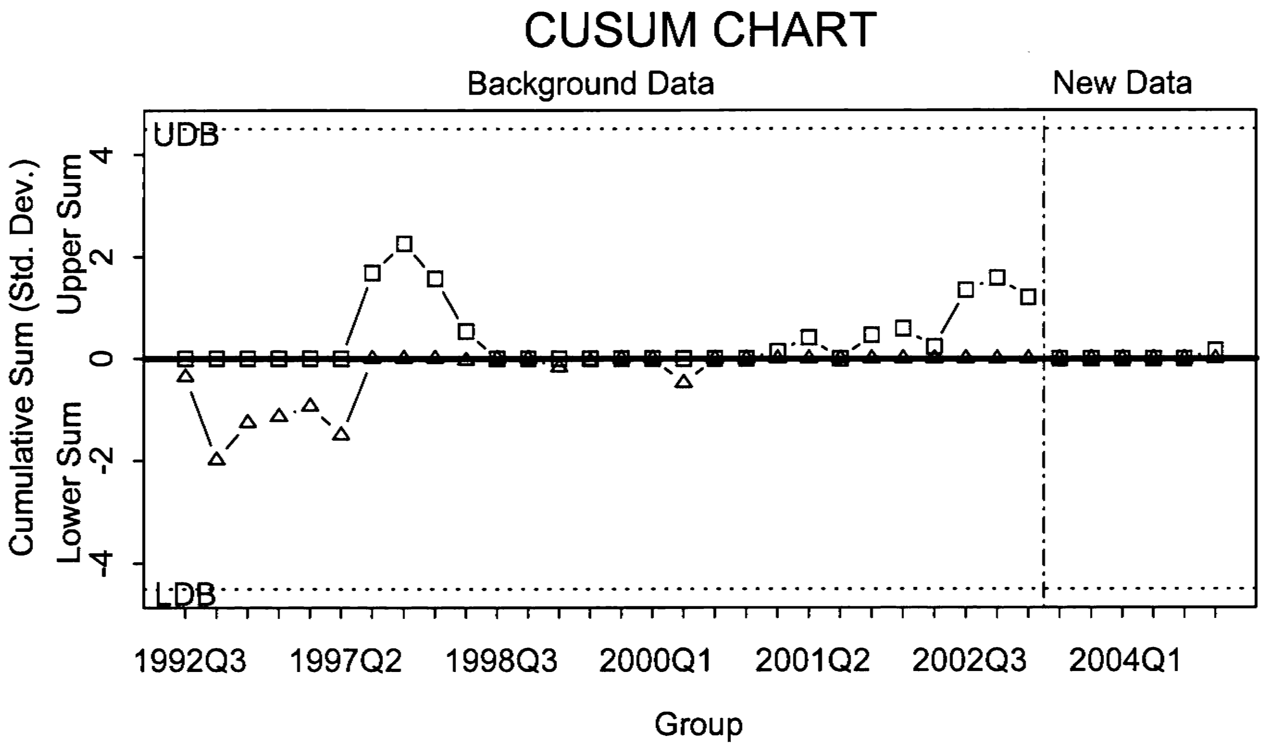


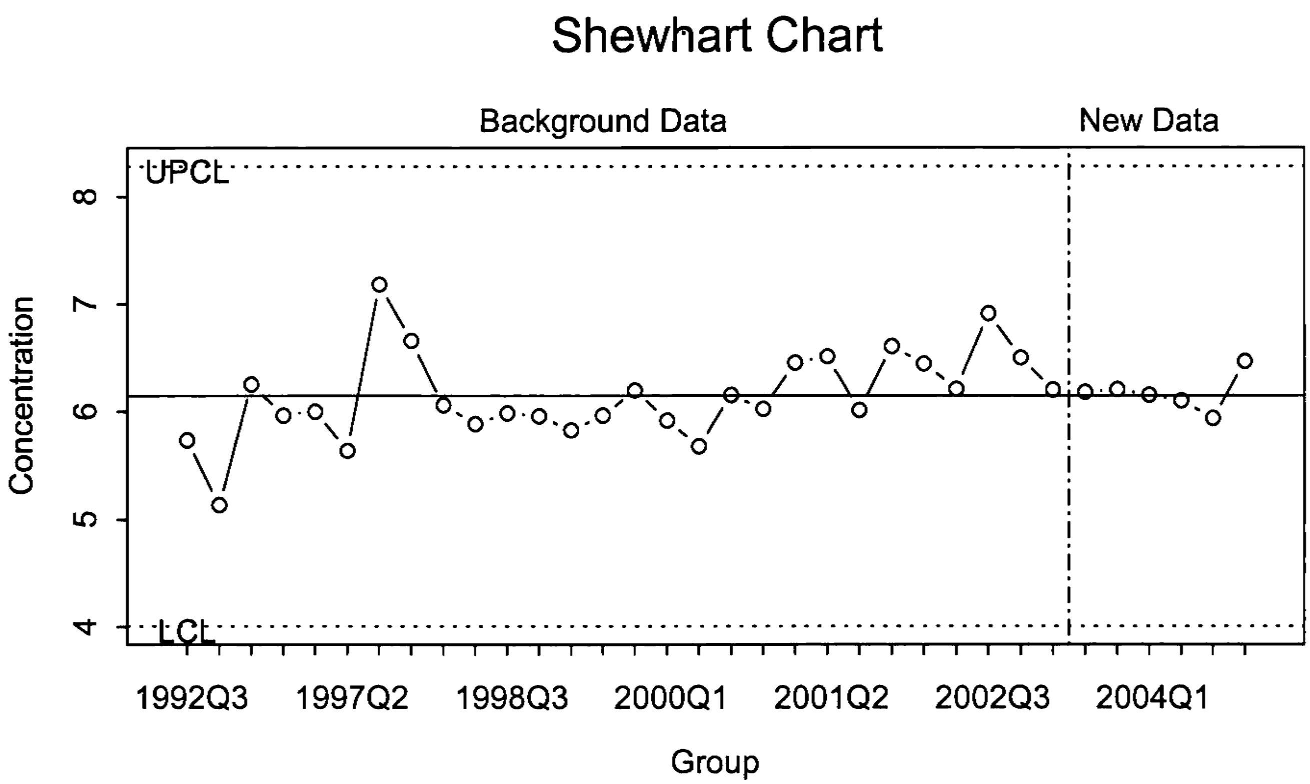
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-63S
Sodium, Dissolved
Log(mg/l)





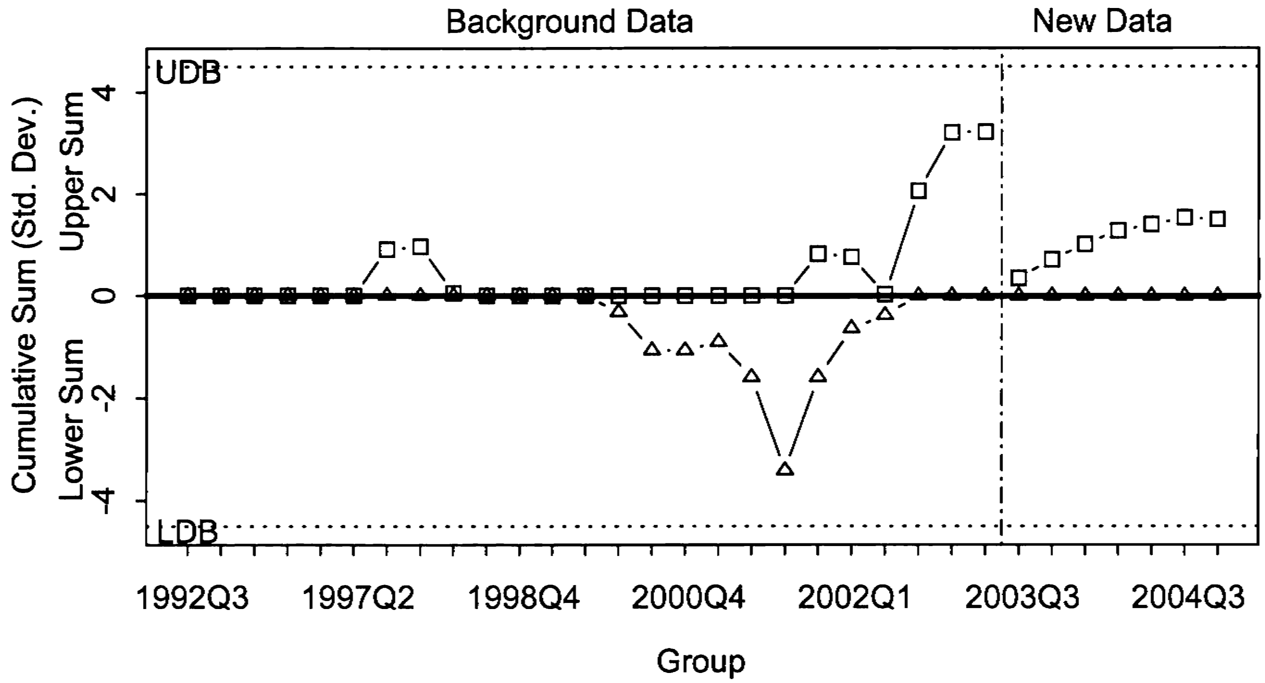
GEOMEGA

5/18/05

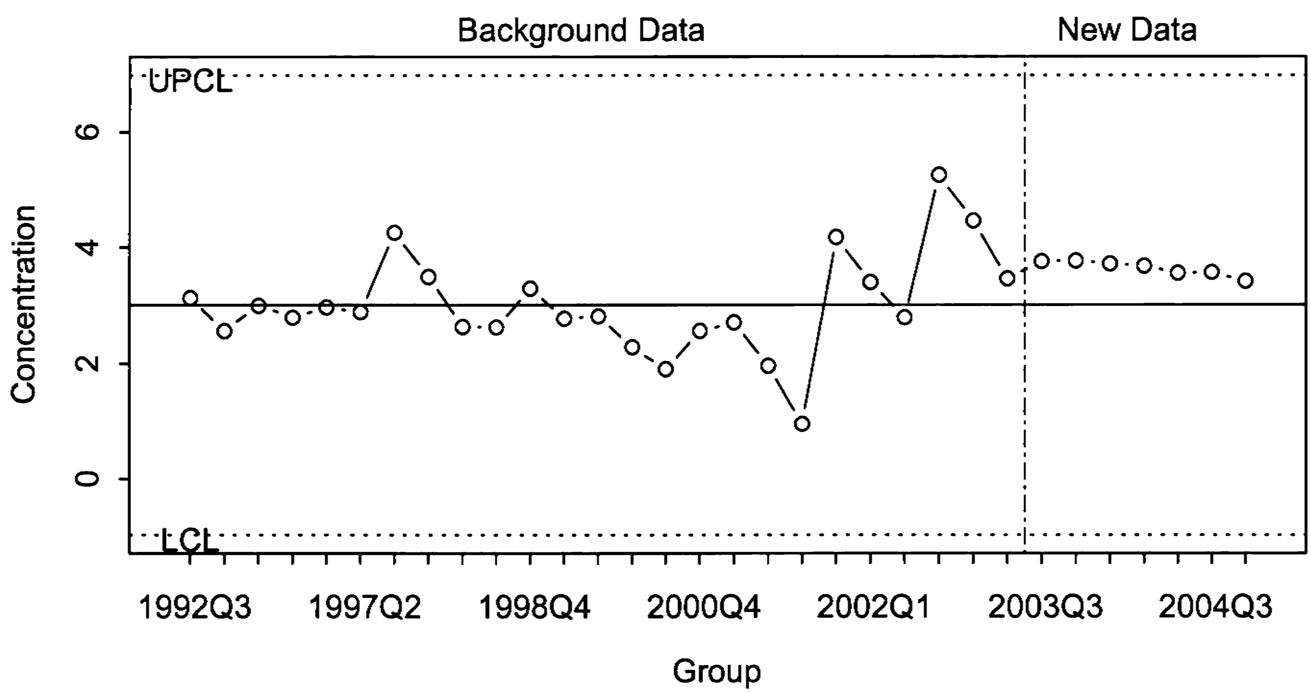
C03302C
Olin-Wilmington

GW-63S
Specific Conductance
Log(mg/l)

CUSUM CHART



Shewhart Chart



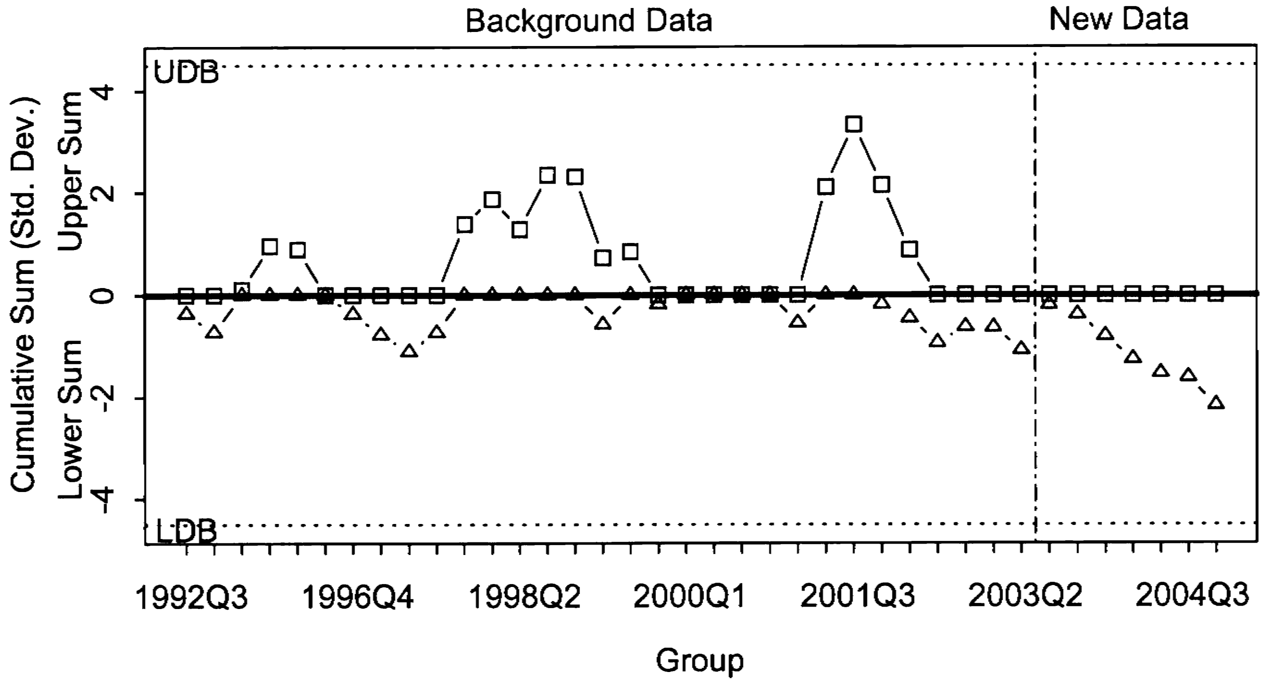
GEOMEGA

5/18/05

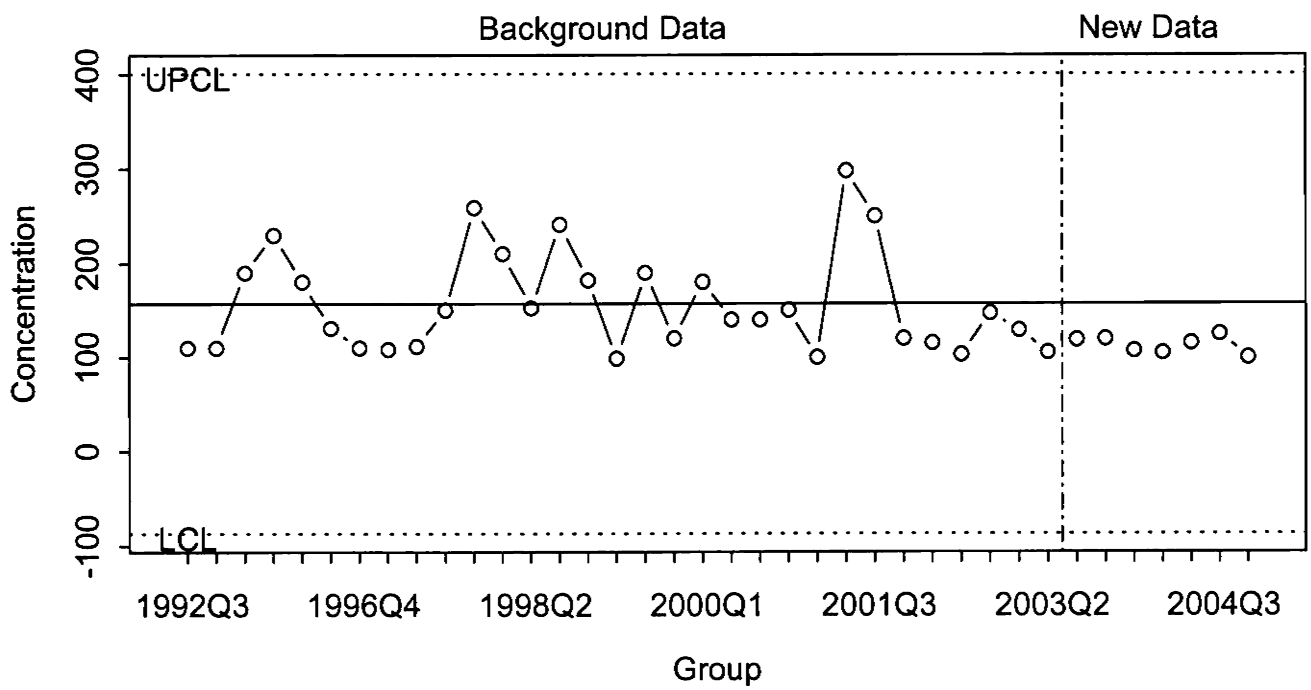
C03302C
Olin-Wilmington

GW-63S
Sulfate as SO4
Log(mg/l)

CUSUM CHART



Shewhart Chart

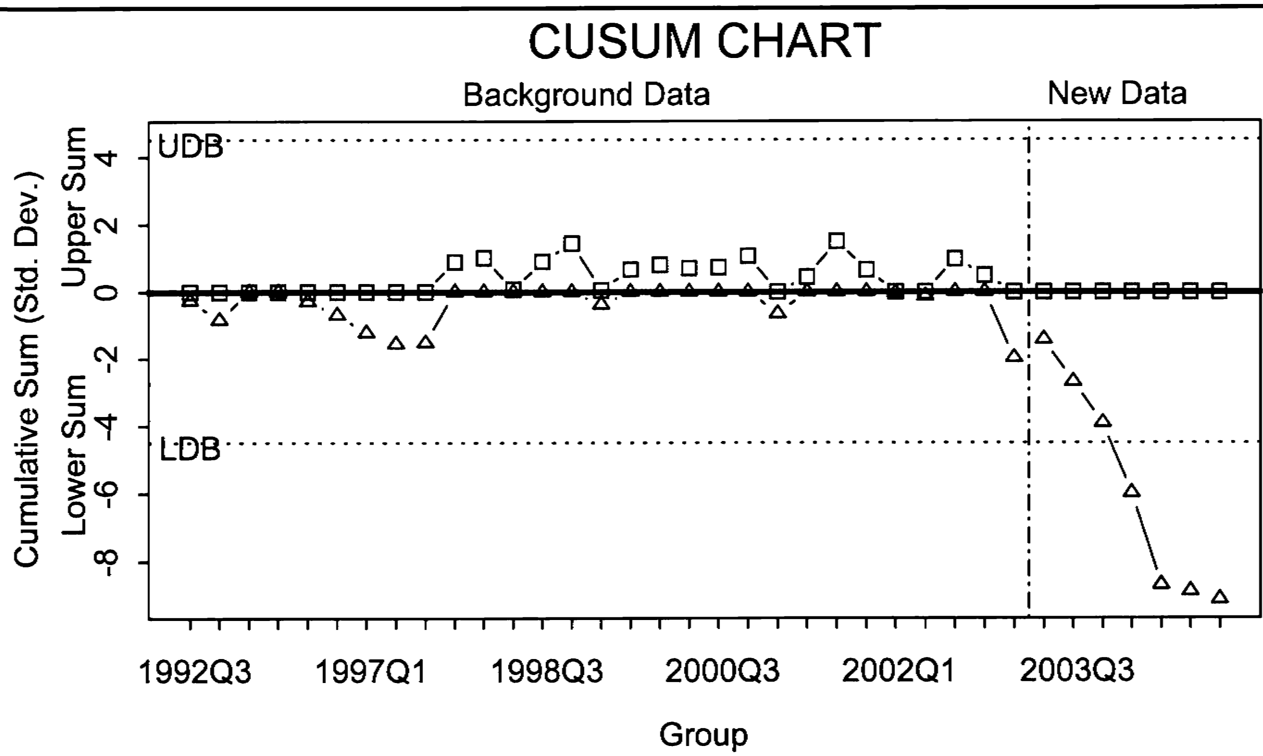


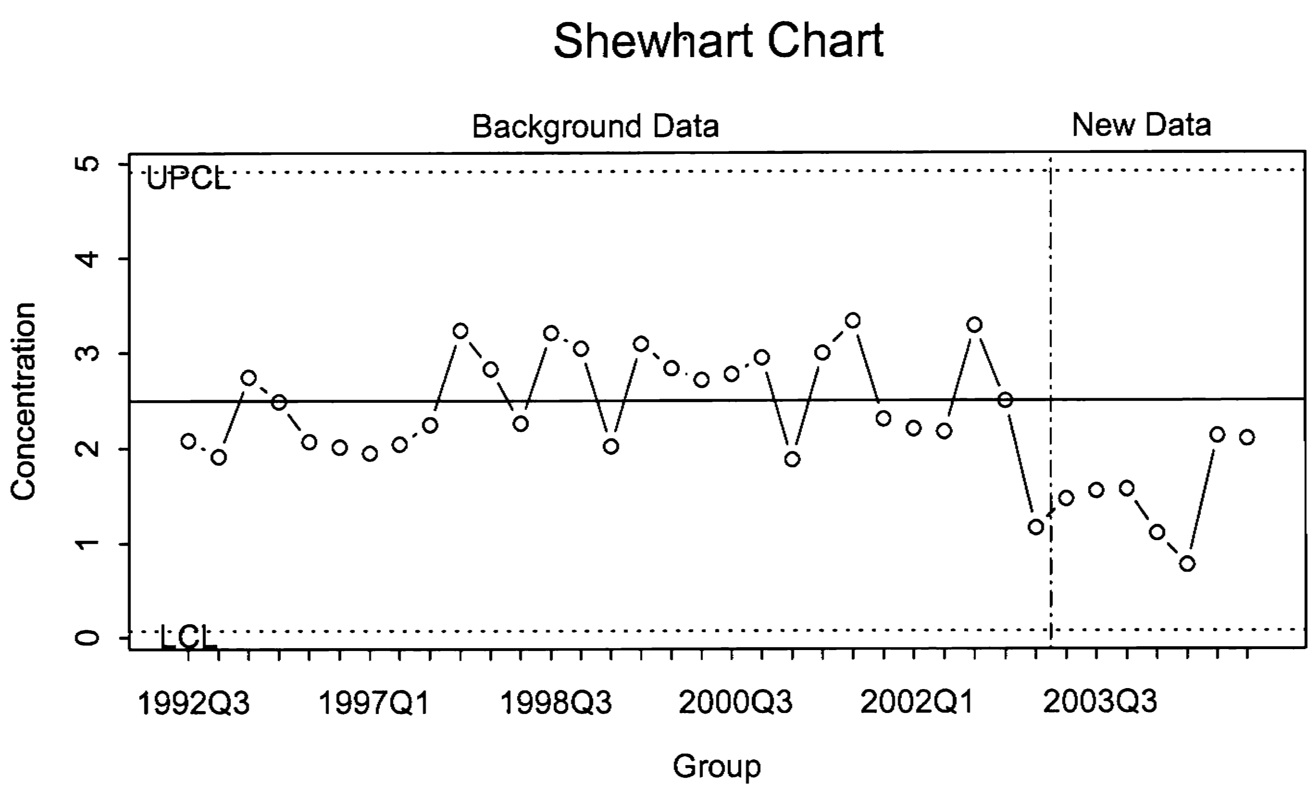
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-64D
Chloride
mg/l



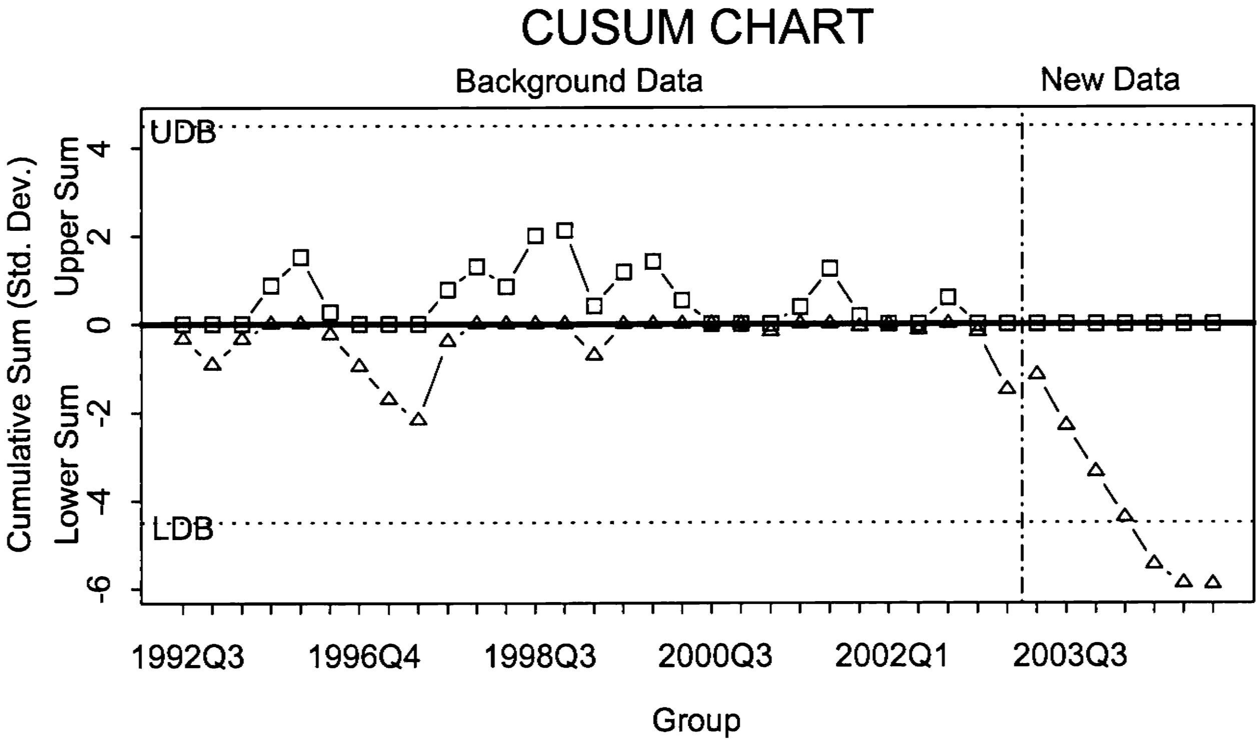


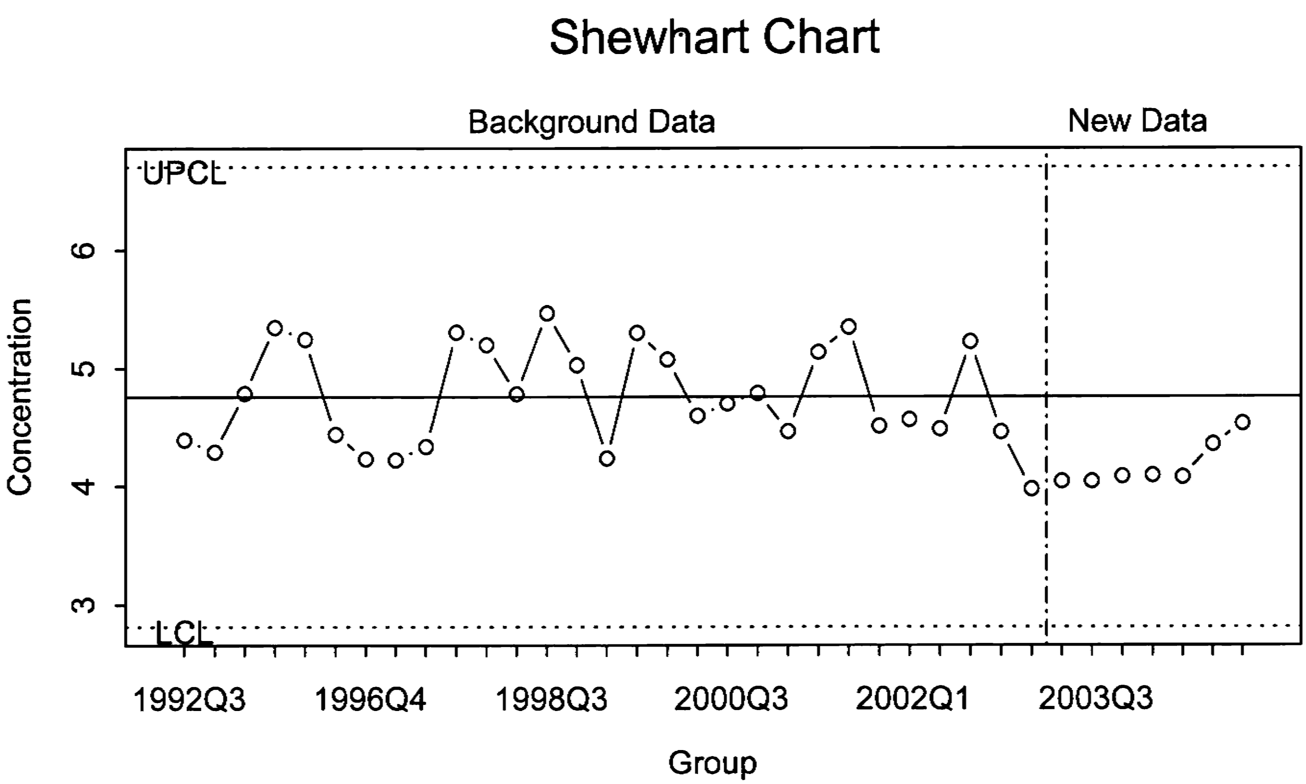
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-64D
Nitrogen, Ammonia
Log(mg/l)



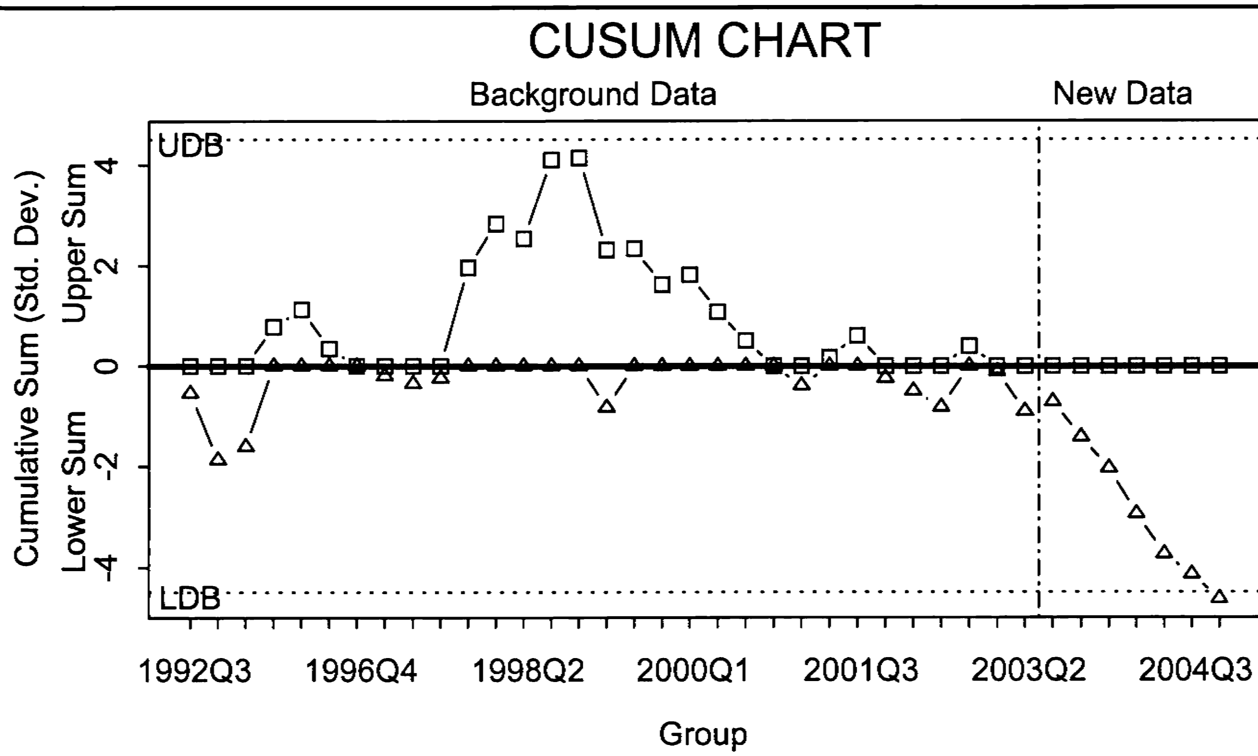


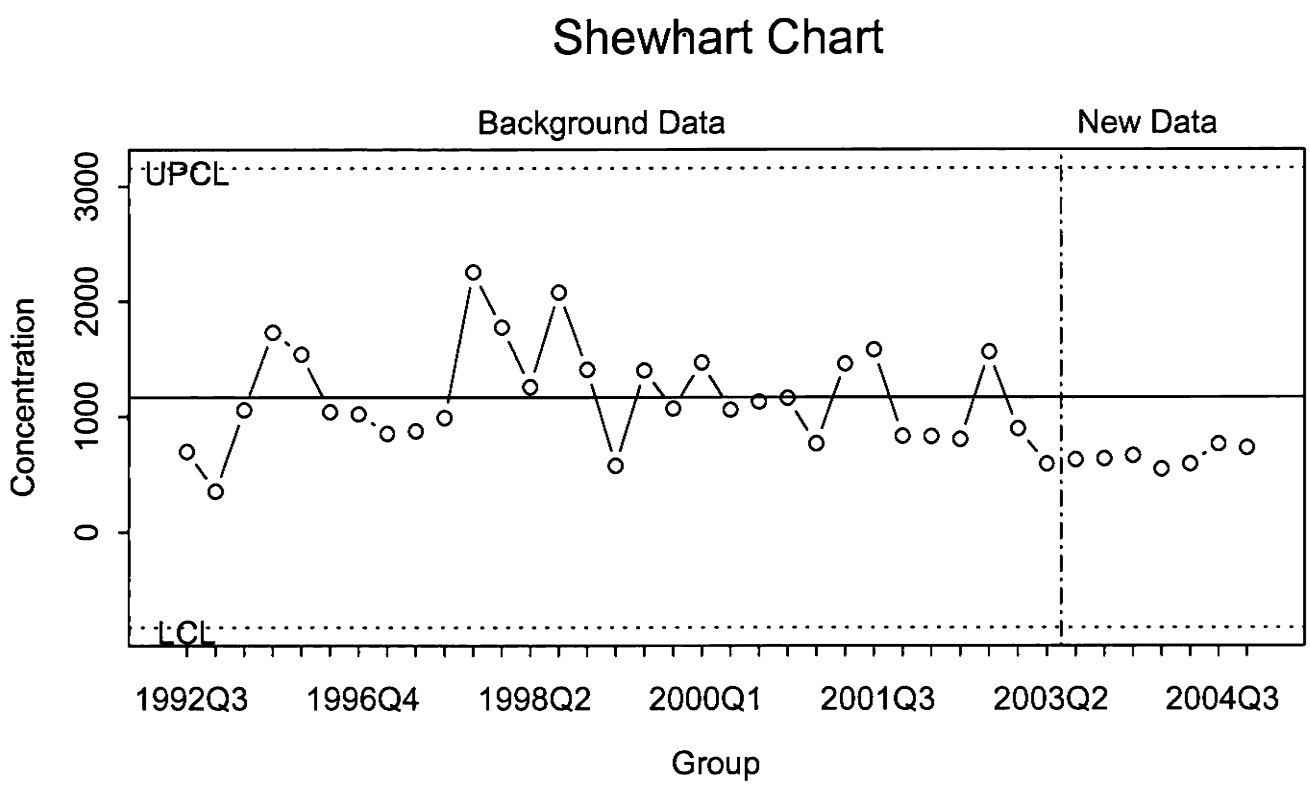
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-64D
Sodium, Dissolved
Log(mg/l)



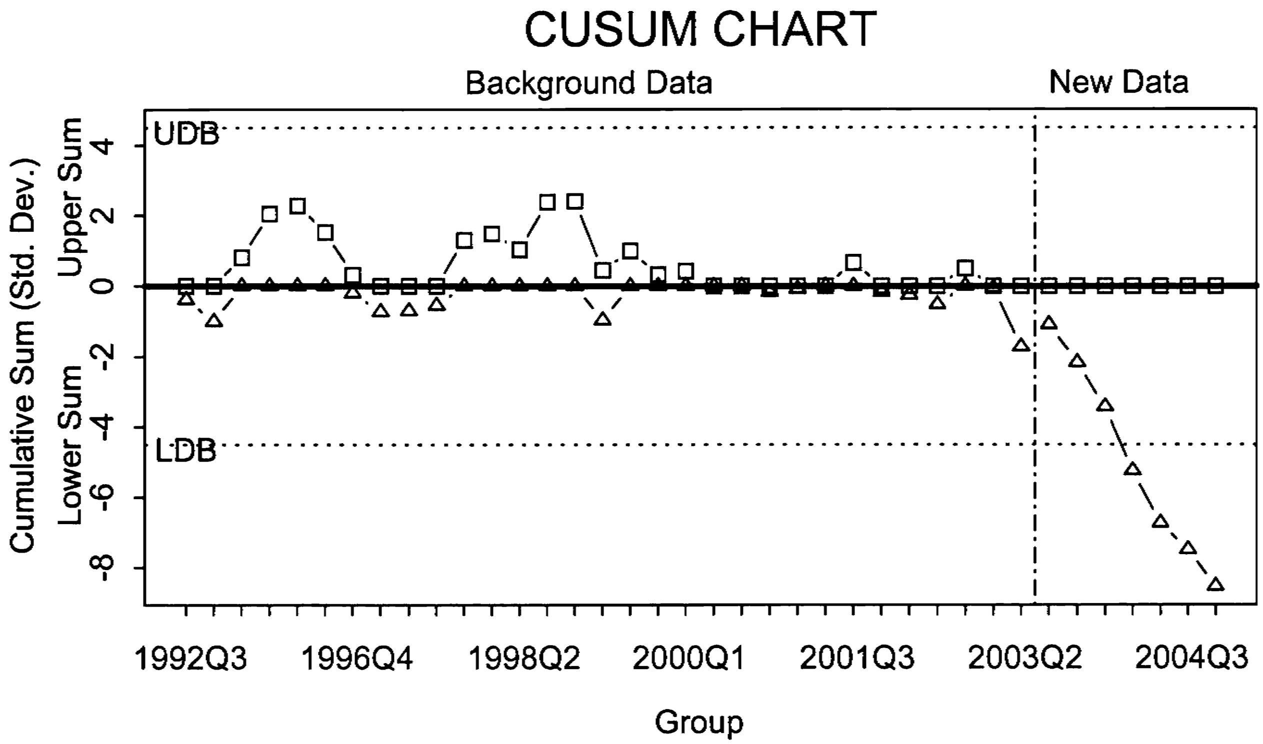


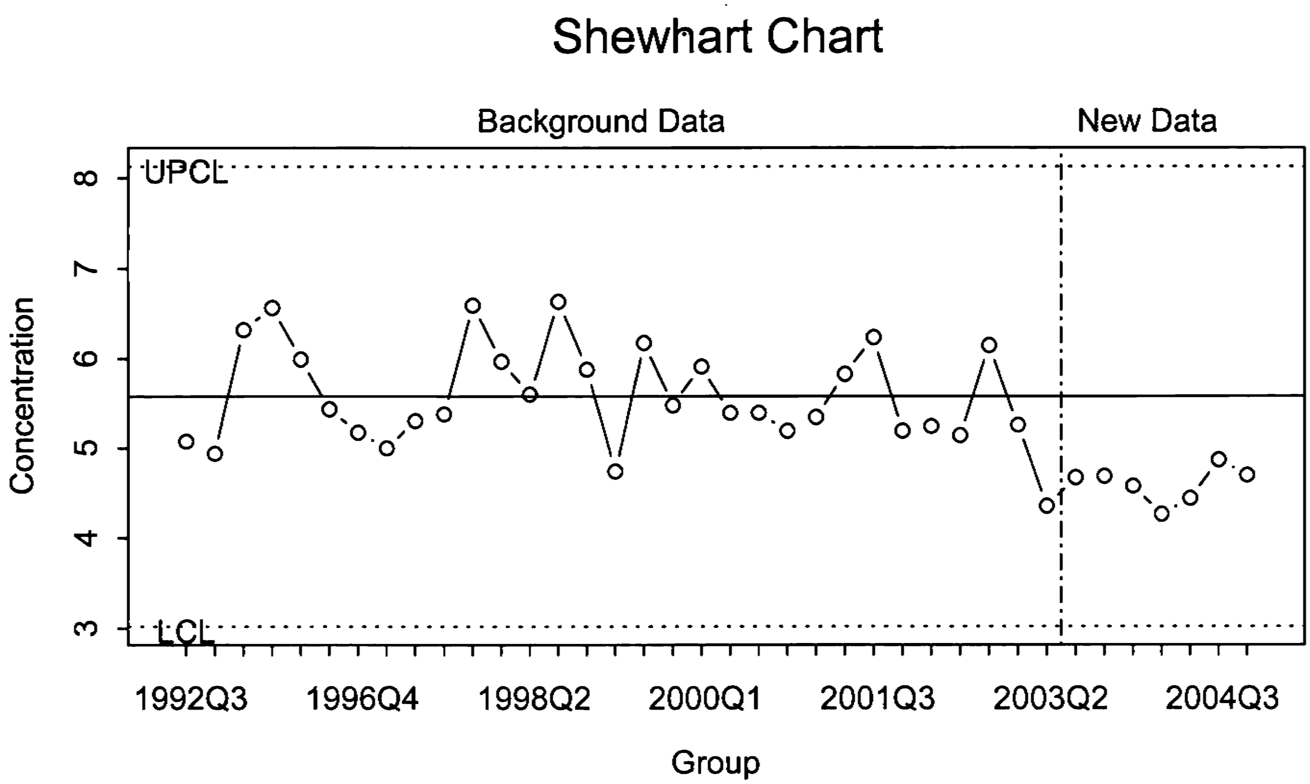
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-64D
Specific Conductance
umhos/cm



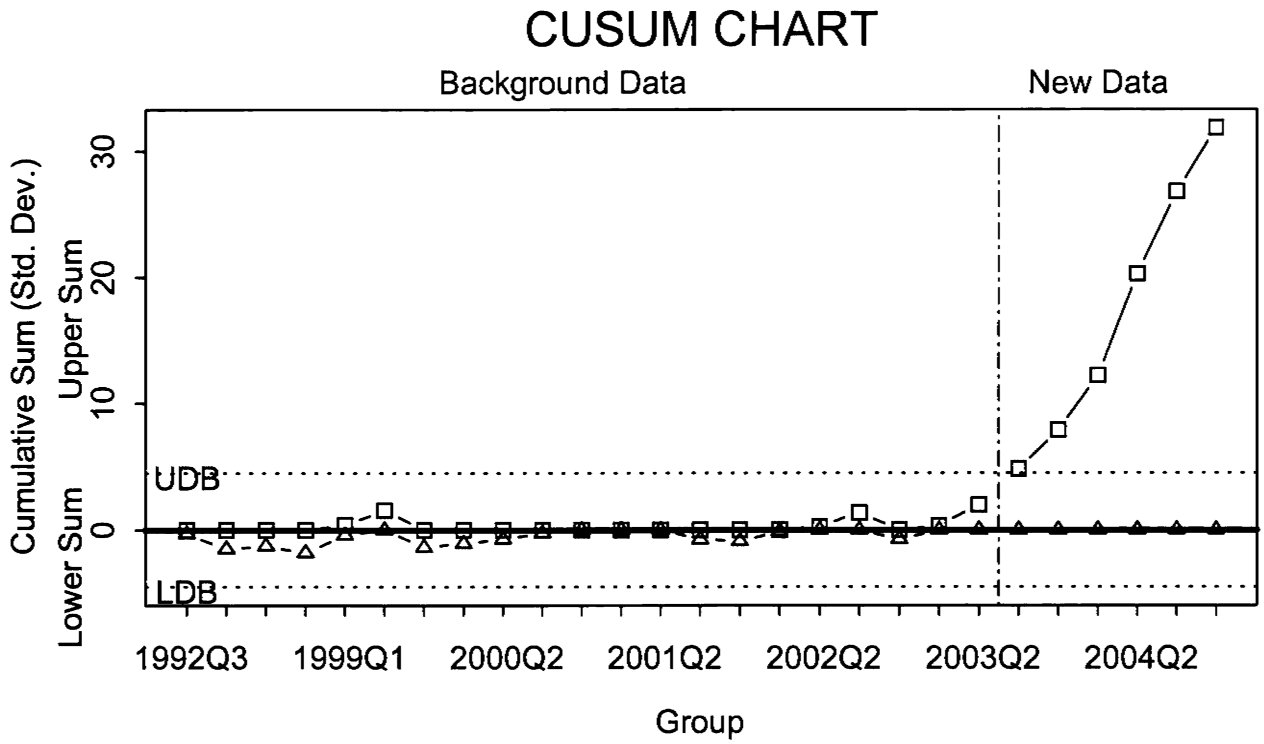


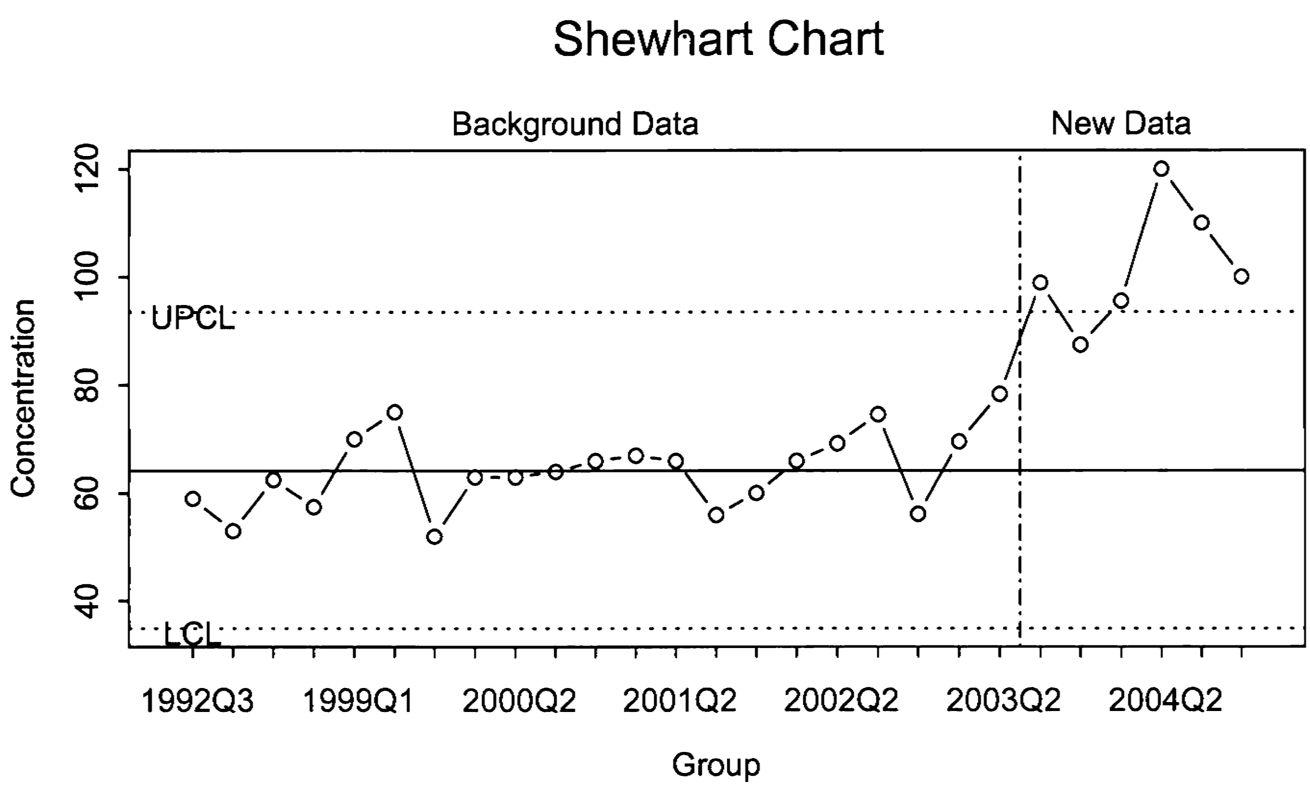
GEOMEGA

5/18/05

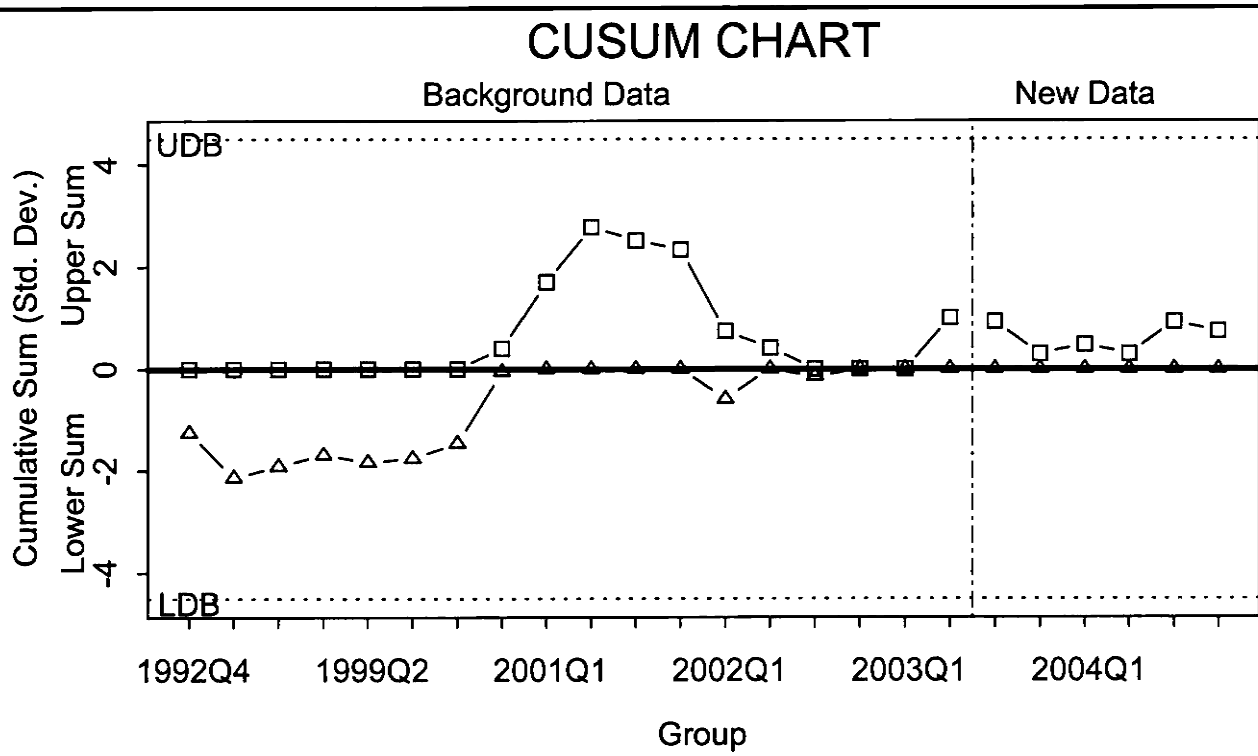
C03302C
Olin-Wilmington

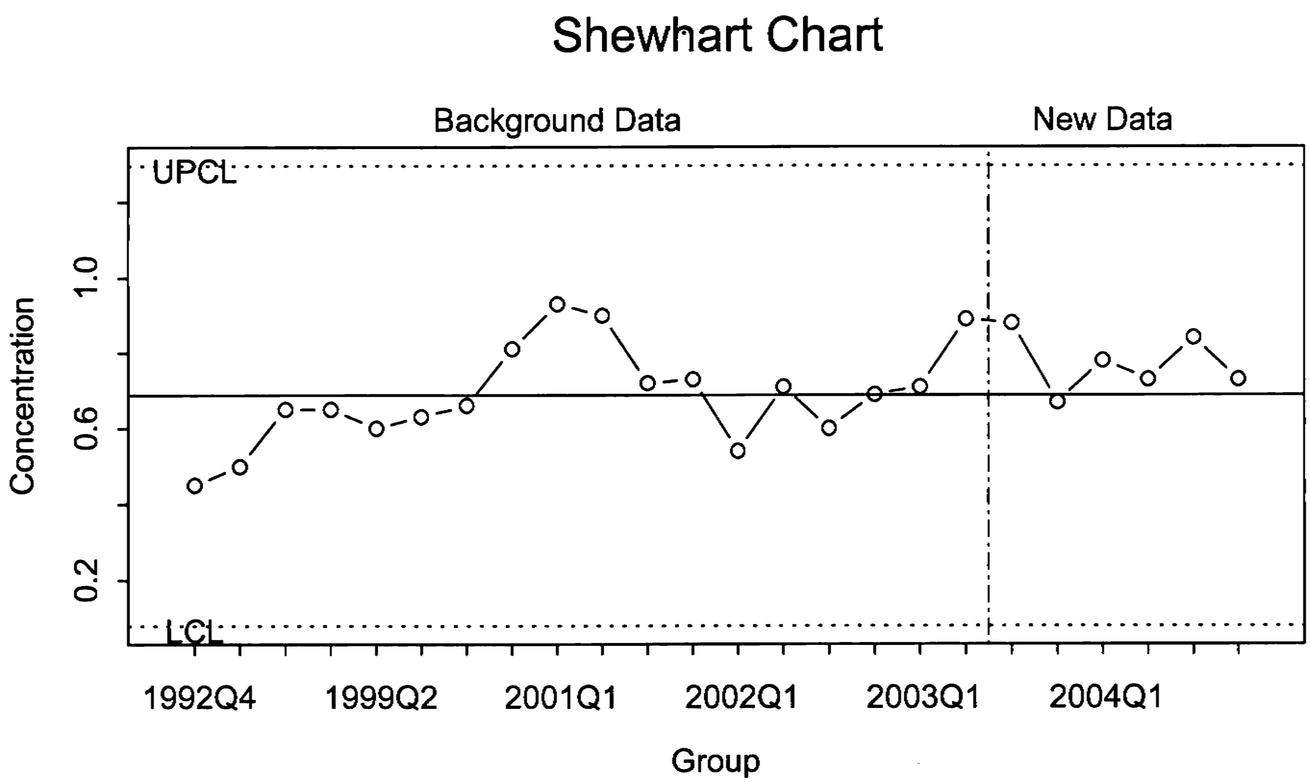
GW-64D
Sulfate as SO4
Log(mg/l)





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-65D Chloride mg/l	



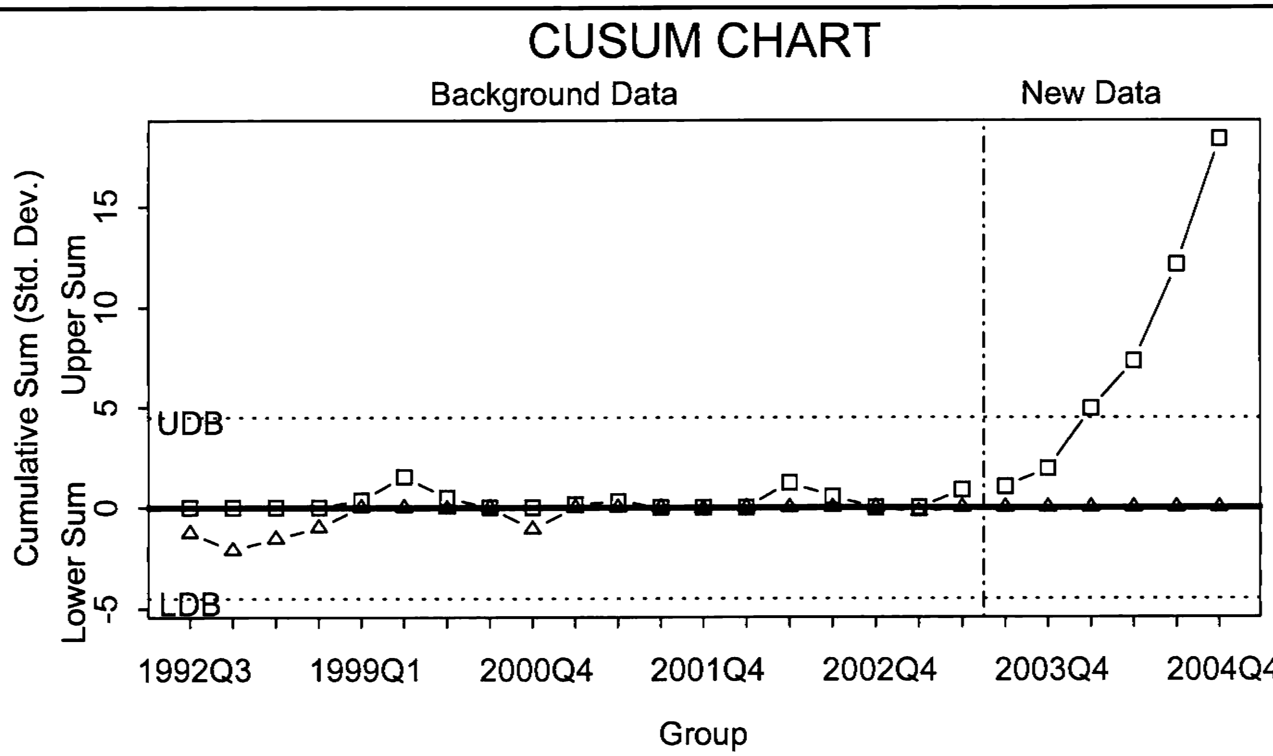


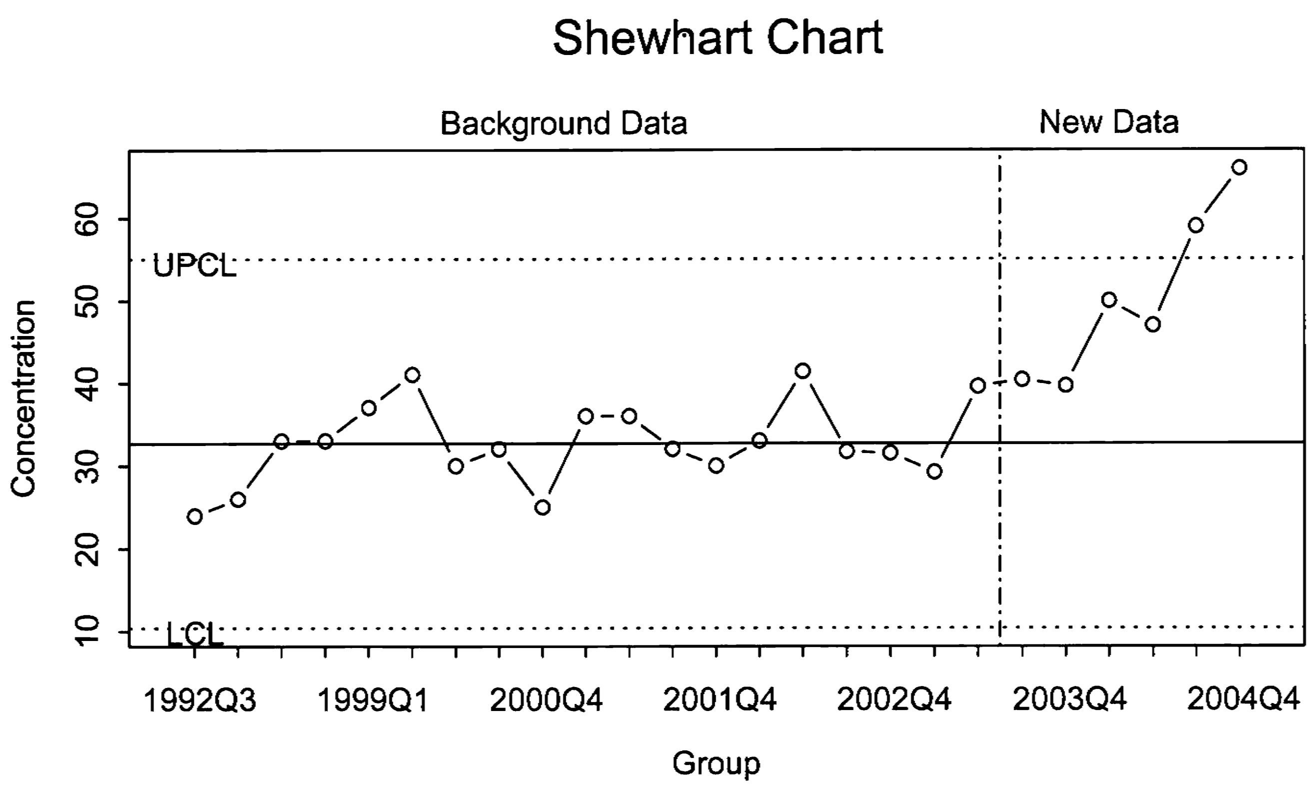
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-65D
Nitrogen, Ammonia
mg/l





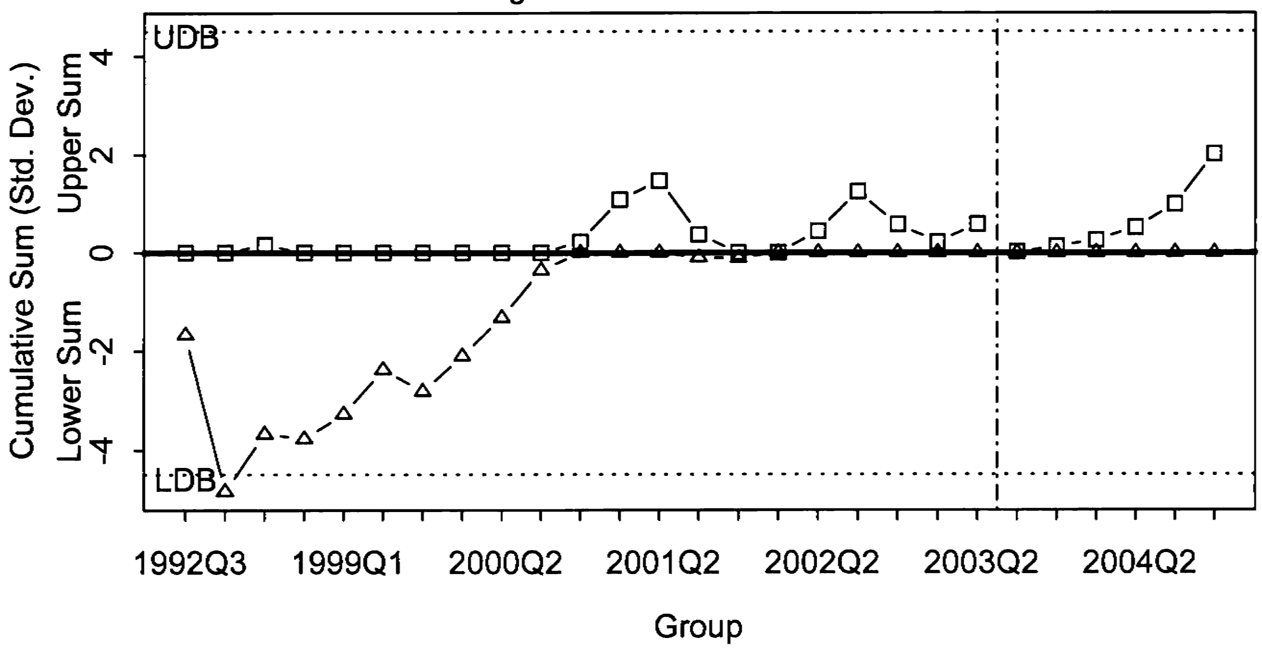
GEOMEGA

5/18/05

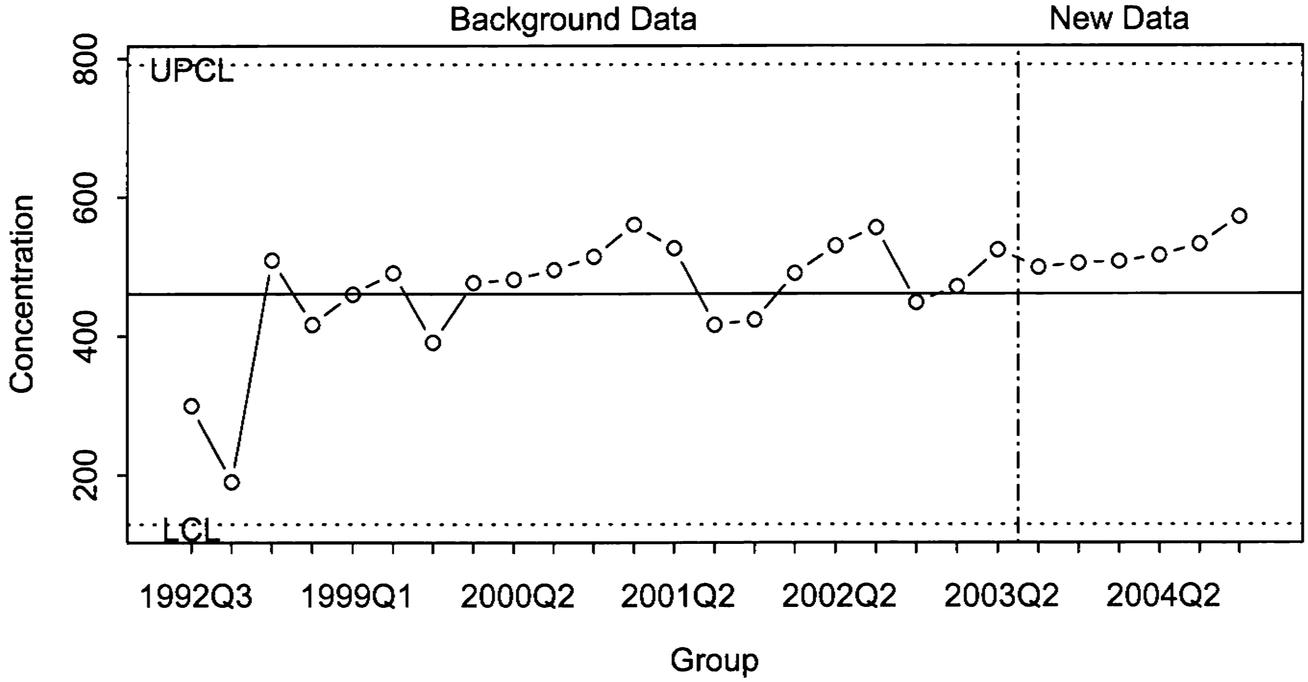
C03302C
Olin-Wilmington

GW-65D
Sodium, Dissolved
mg/l

CUSUM CHART



Shewhart Chart

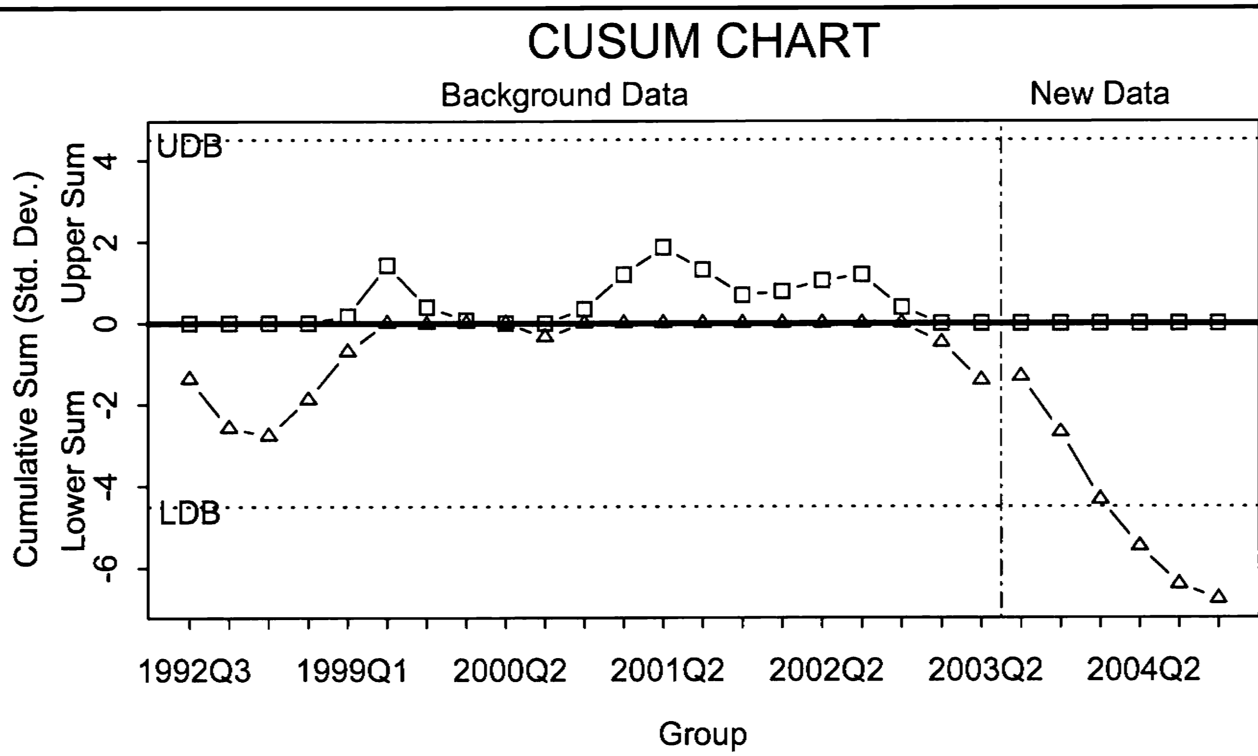


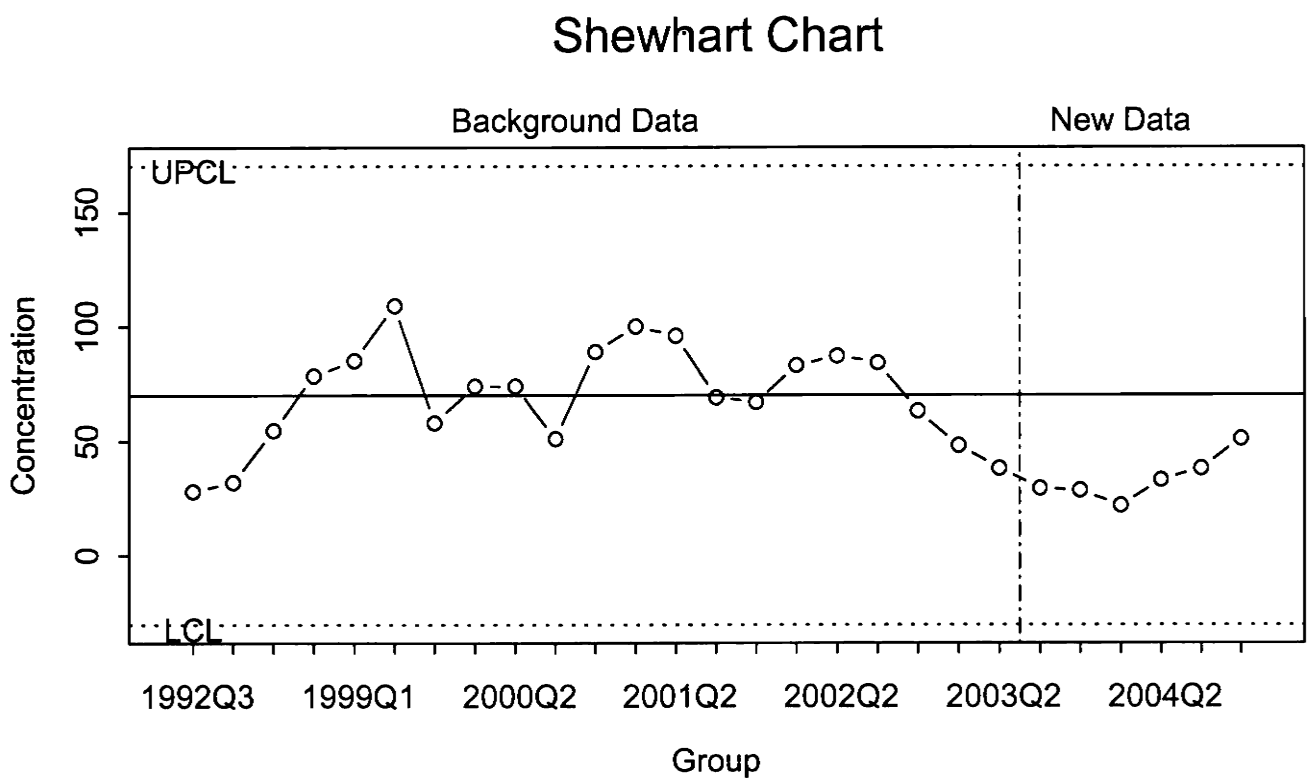
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-65D
Specific Conductance
umhos/cm



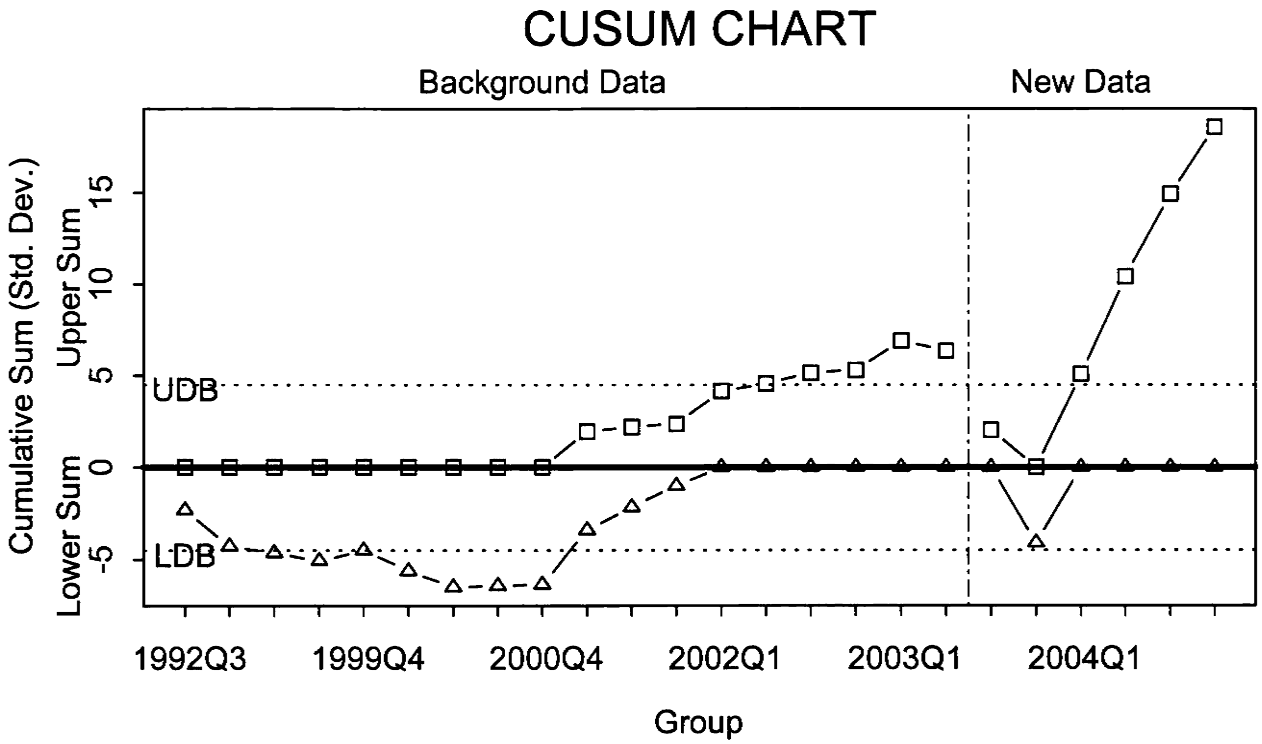


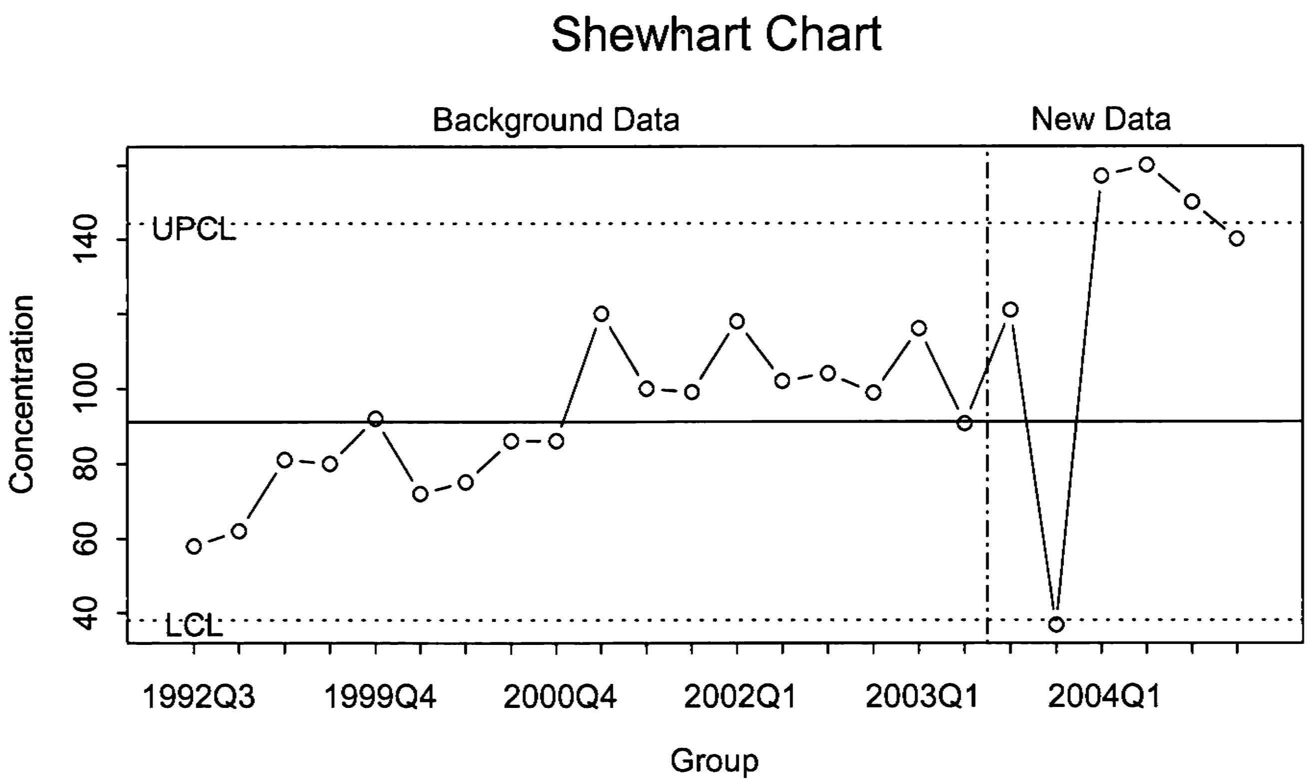
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-65D
Sulfate as SO4
mg/l



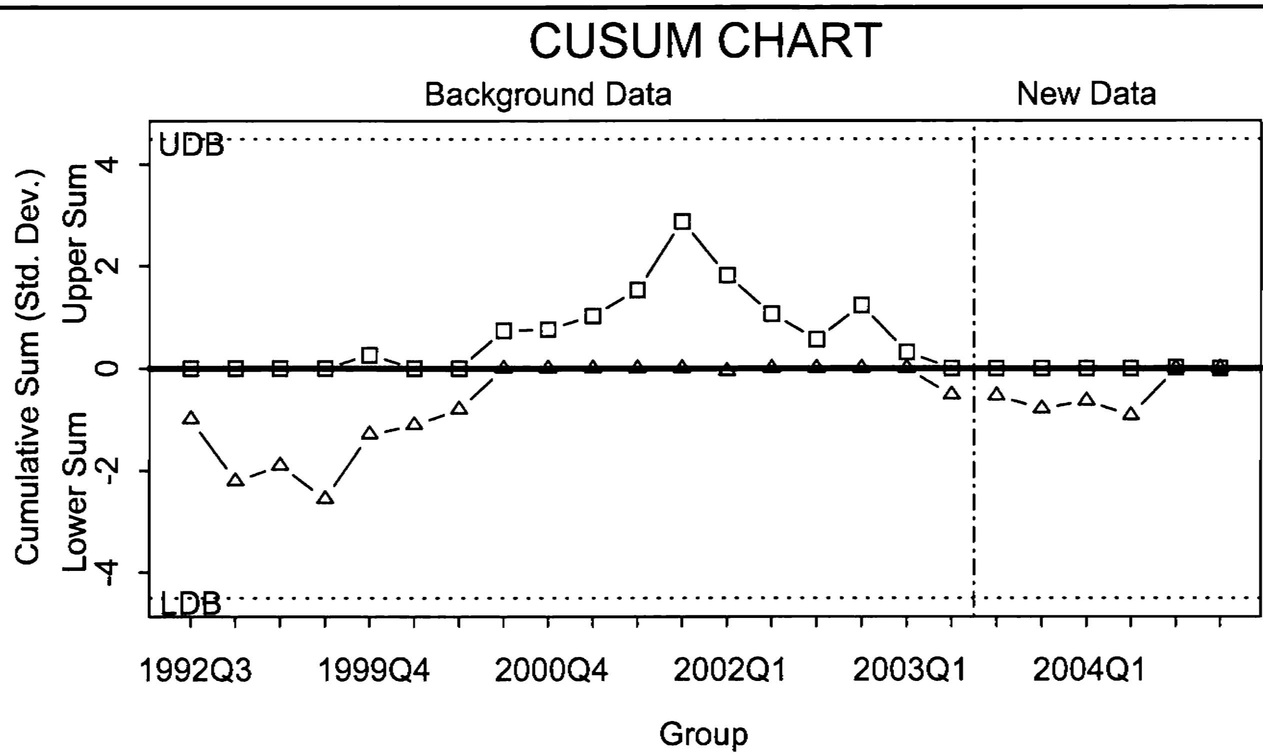


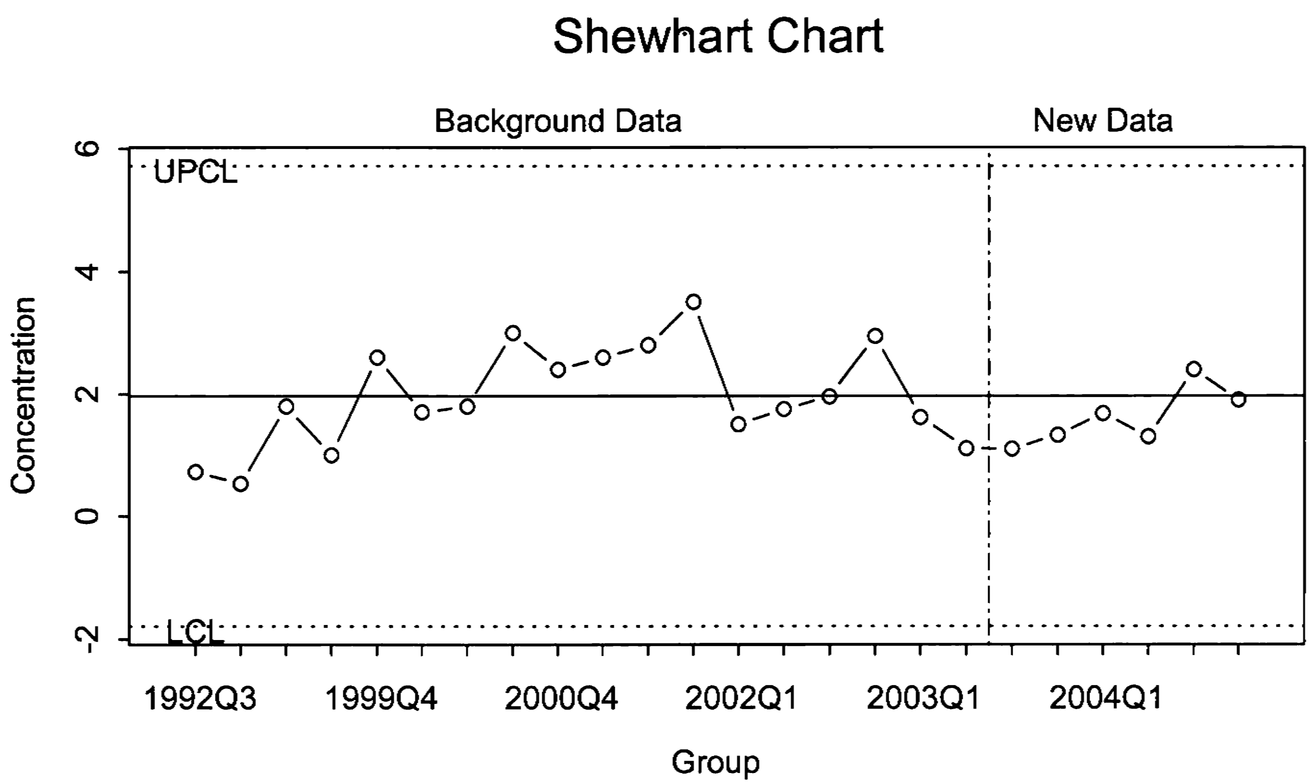
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-65S
Chloride
mg/l





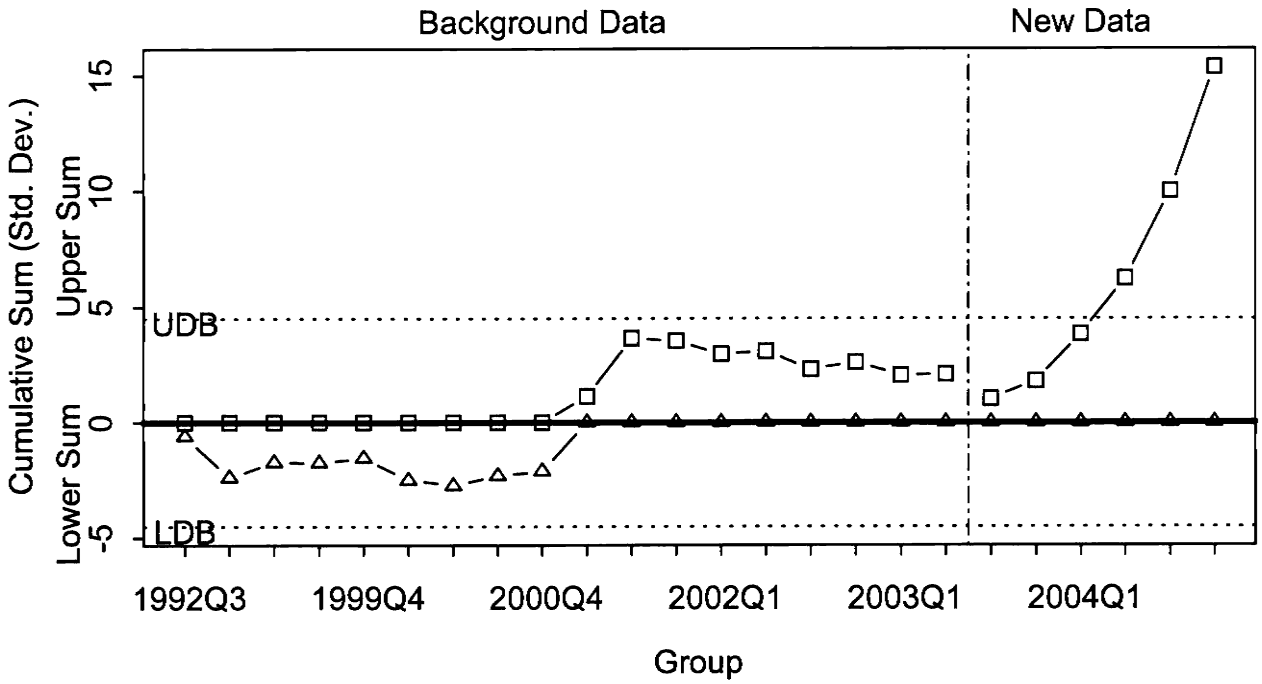
GEOMEGA

5/18/05

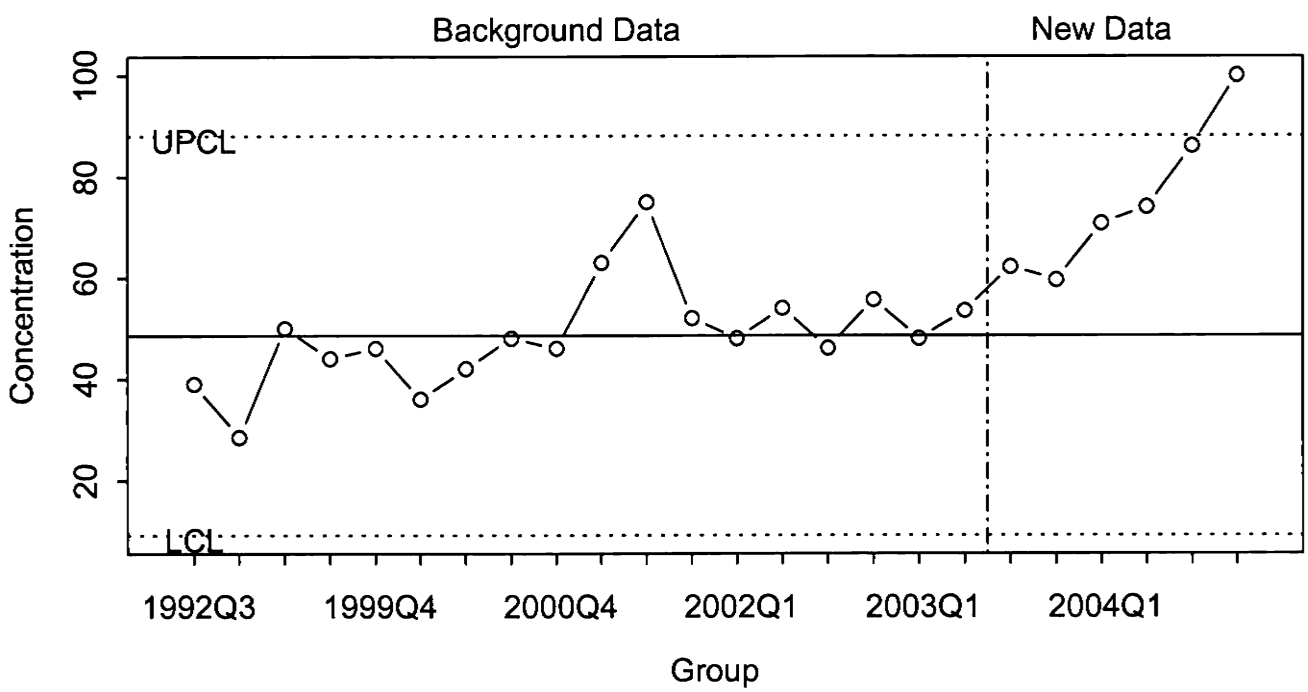
C03302C
Olin-Wilmington

GW-65S
Nitrogen, Ammonia
mg/l

CUSUM CHART



Shewhart Chart

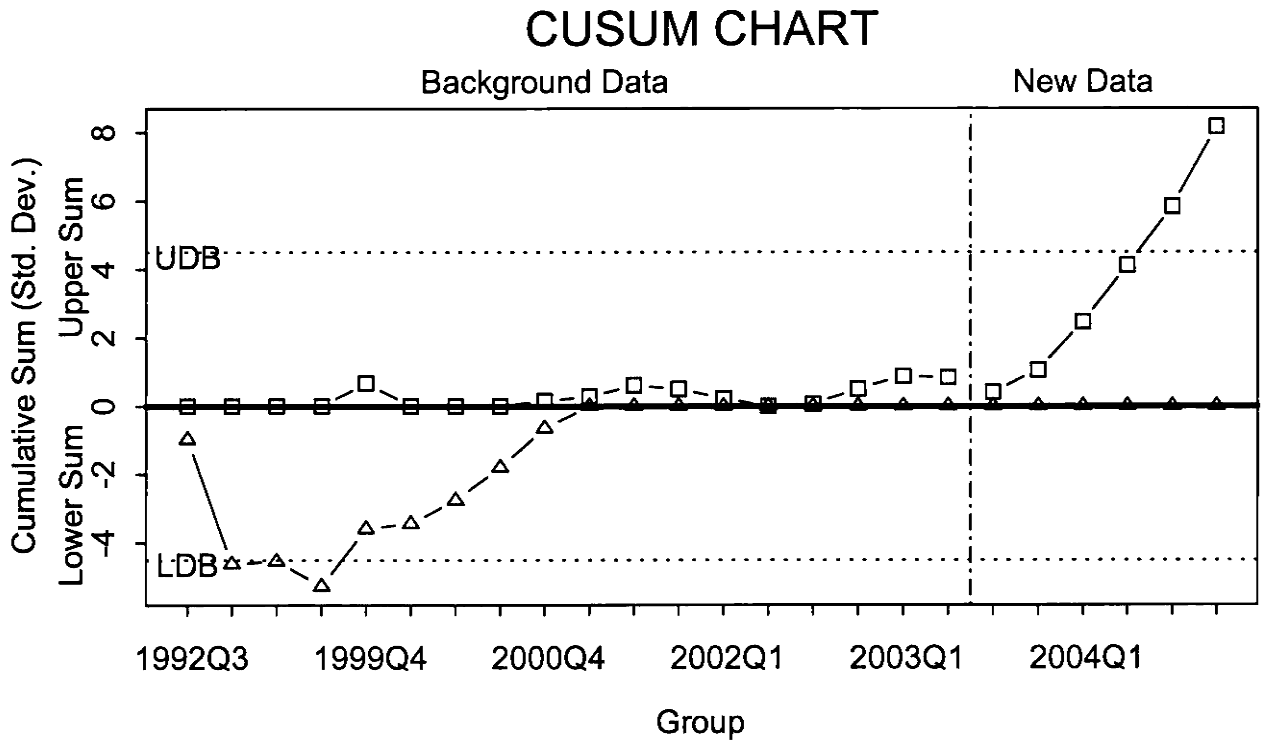


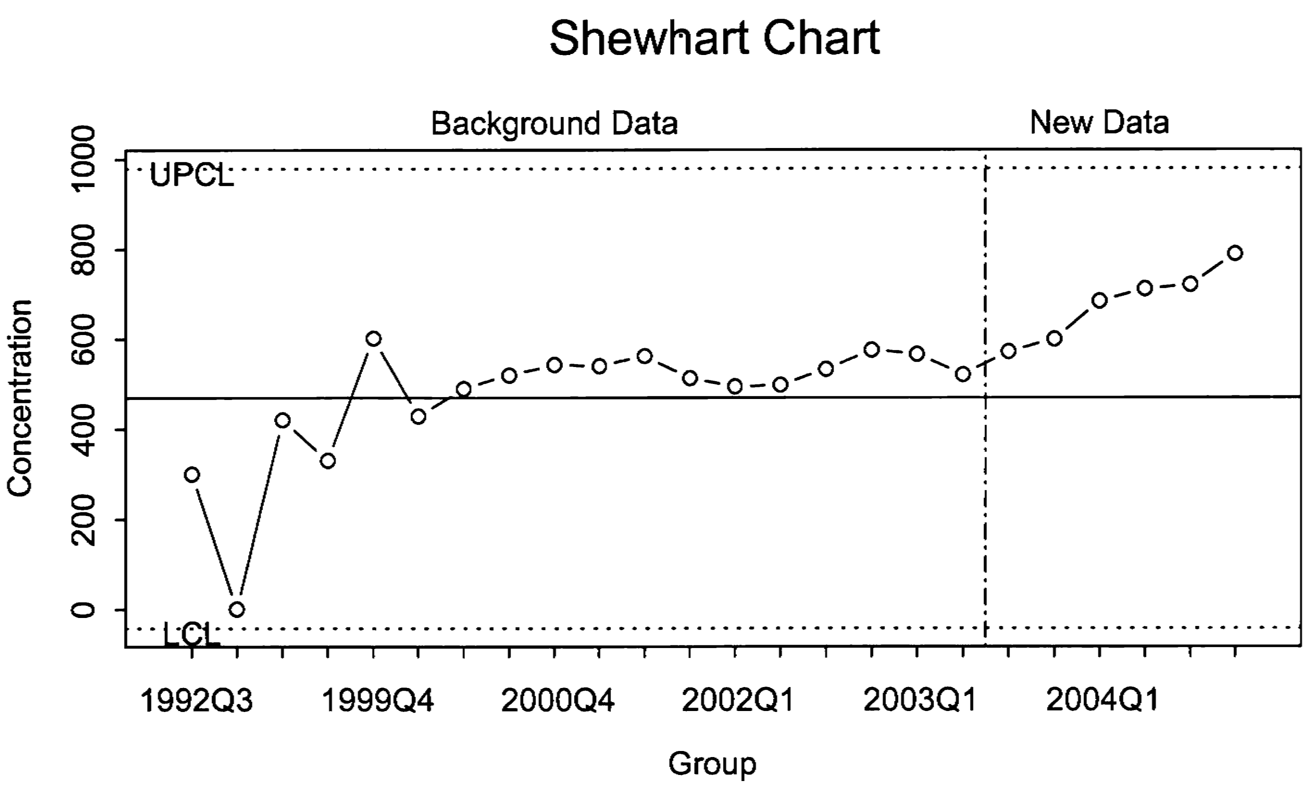
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-65S
Sodium, Dissolved
mg/l



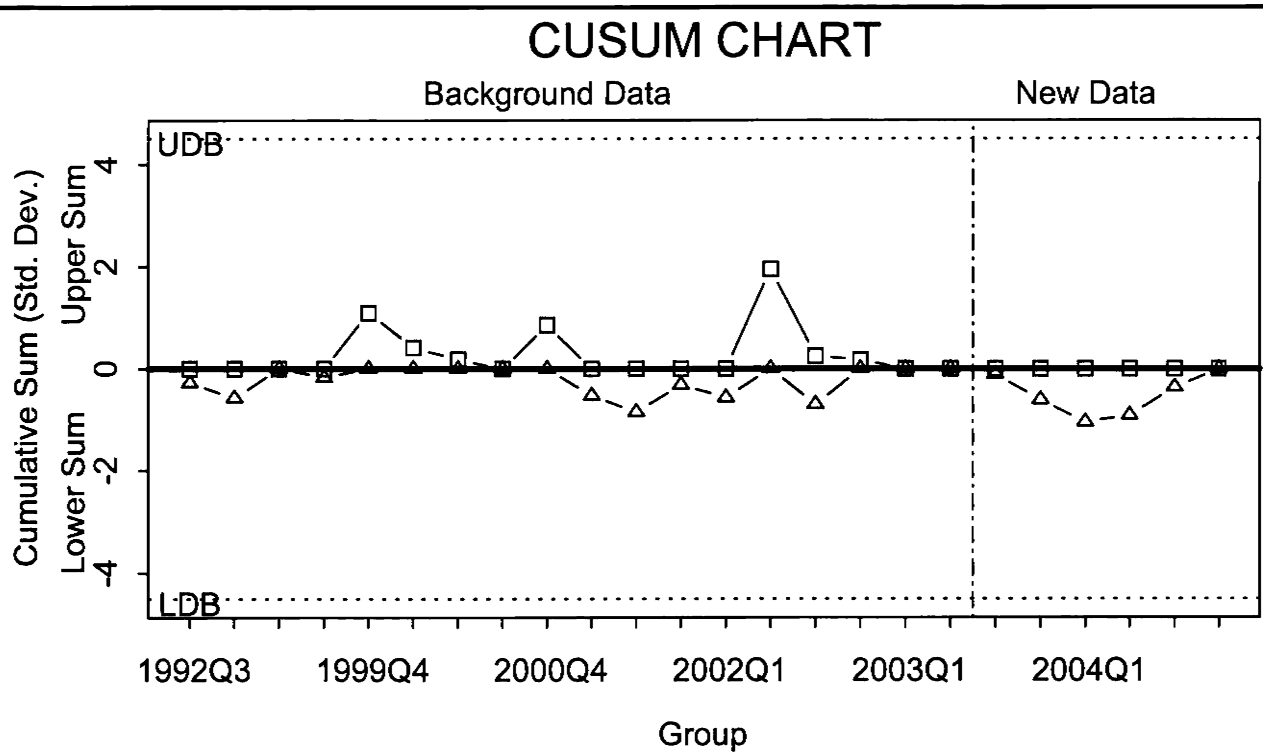


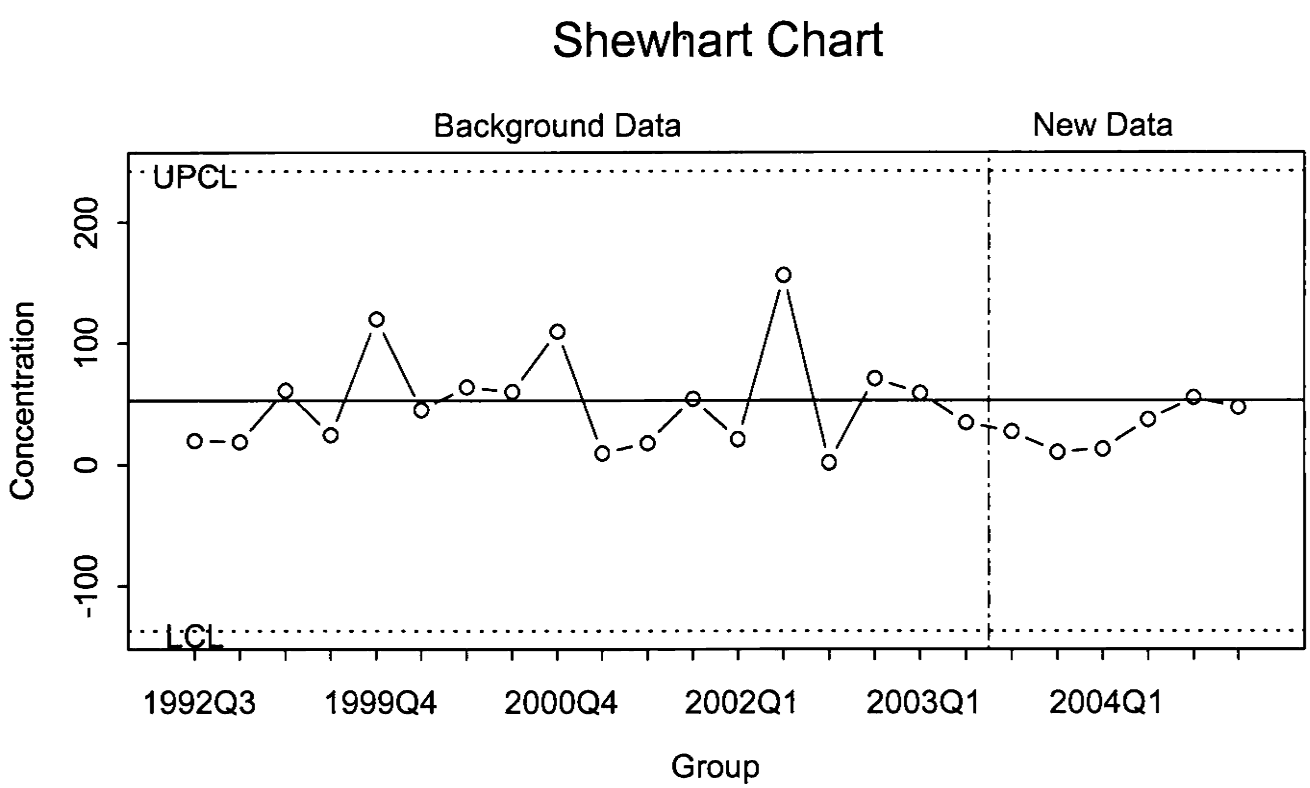
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-65S
Specific Conductance
umhos/cm





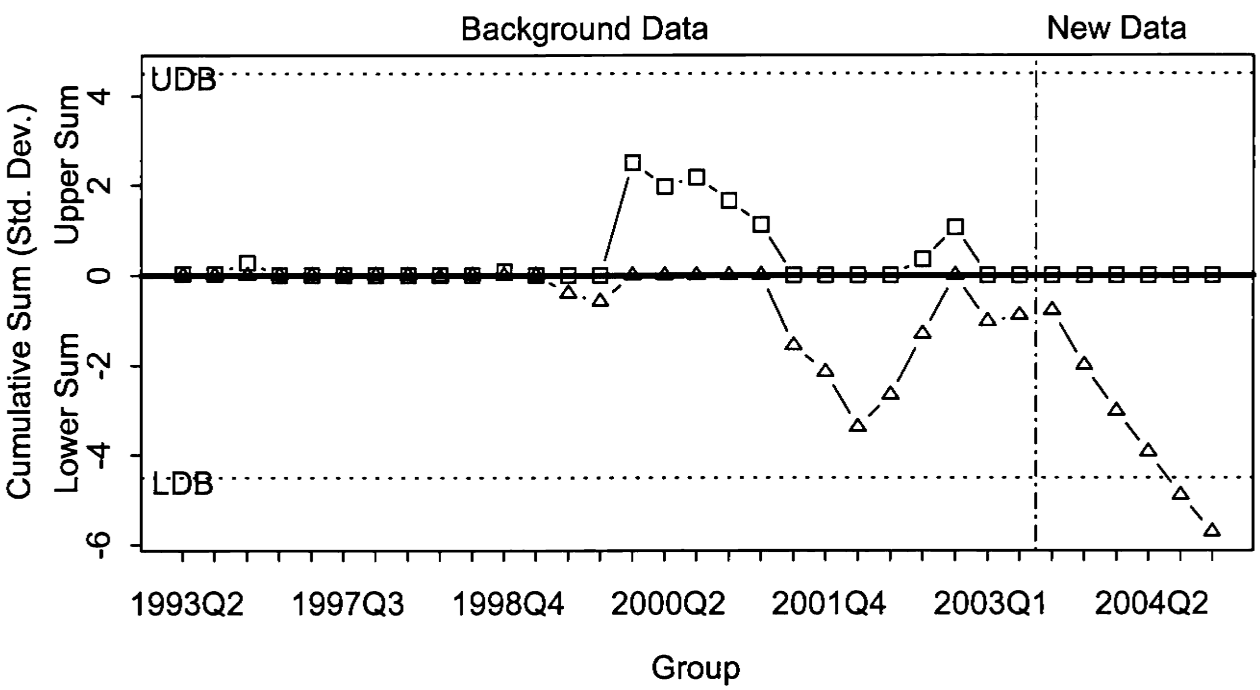
GEOMEGA

5/18/05

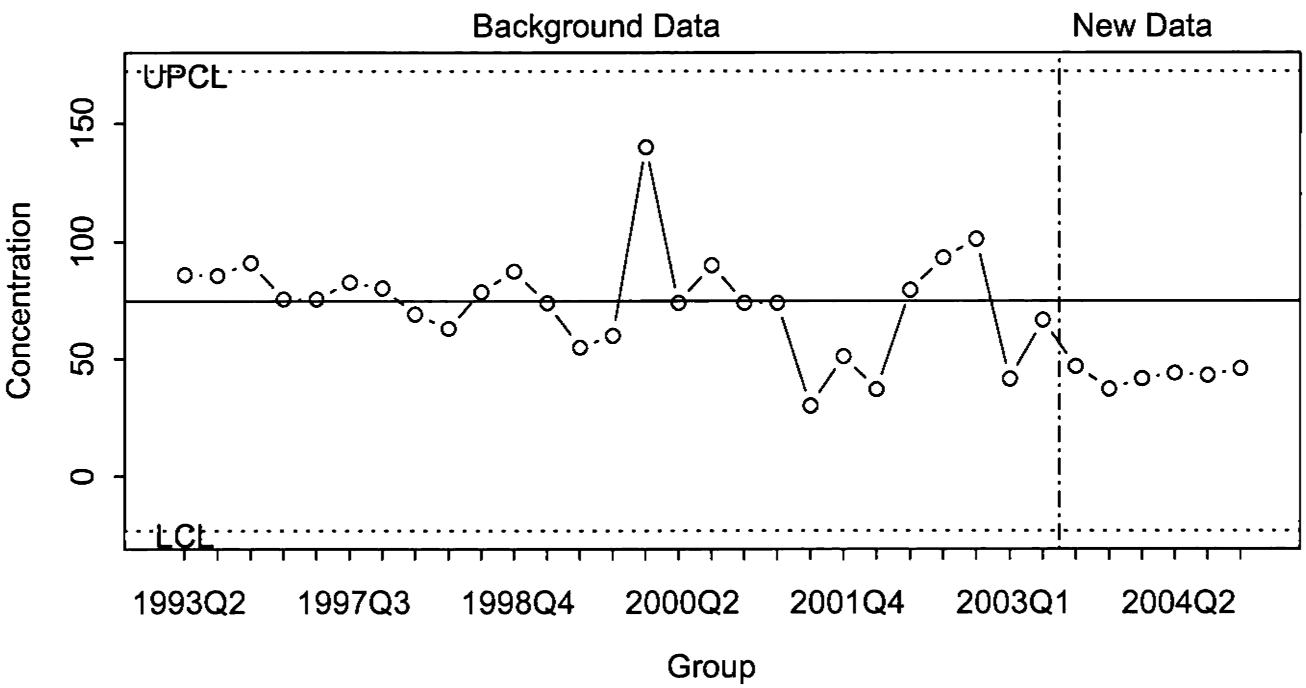
C03302C
Olin-Wilmington

GW-65S
Sulfate as SO4
mg/l

CUSUM CHART

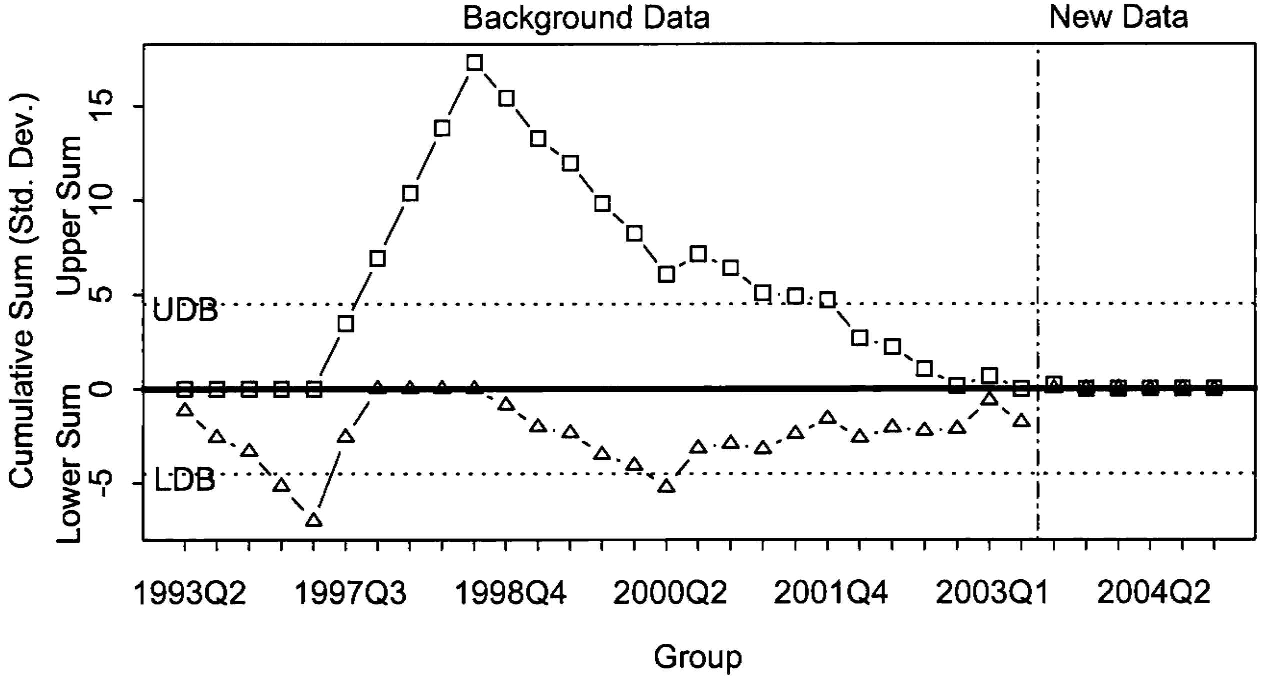


Shewhart Chart

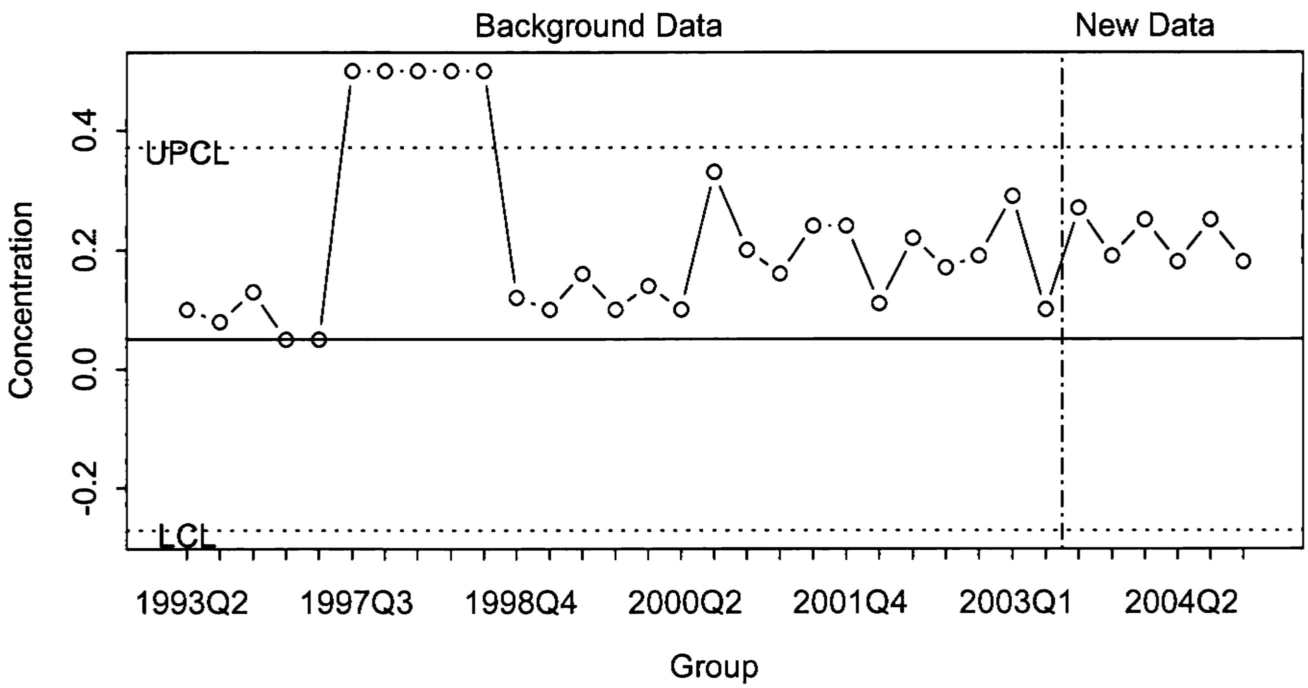


GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-73D Chloride mg/l	

CUSUM CHART



Shewhart Chart

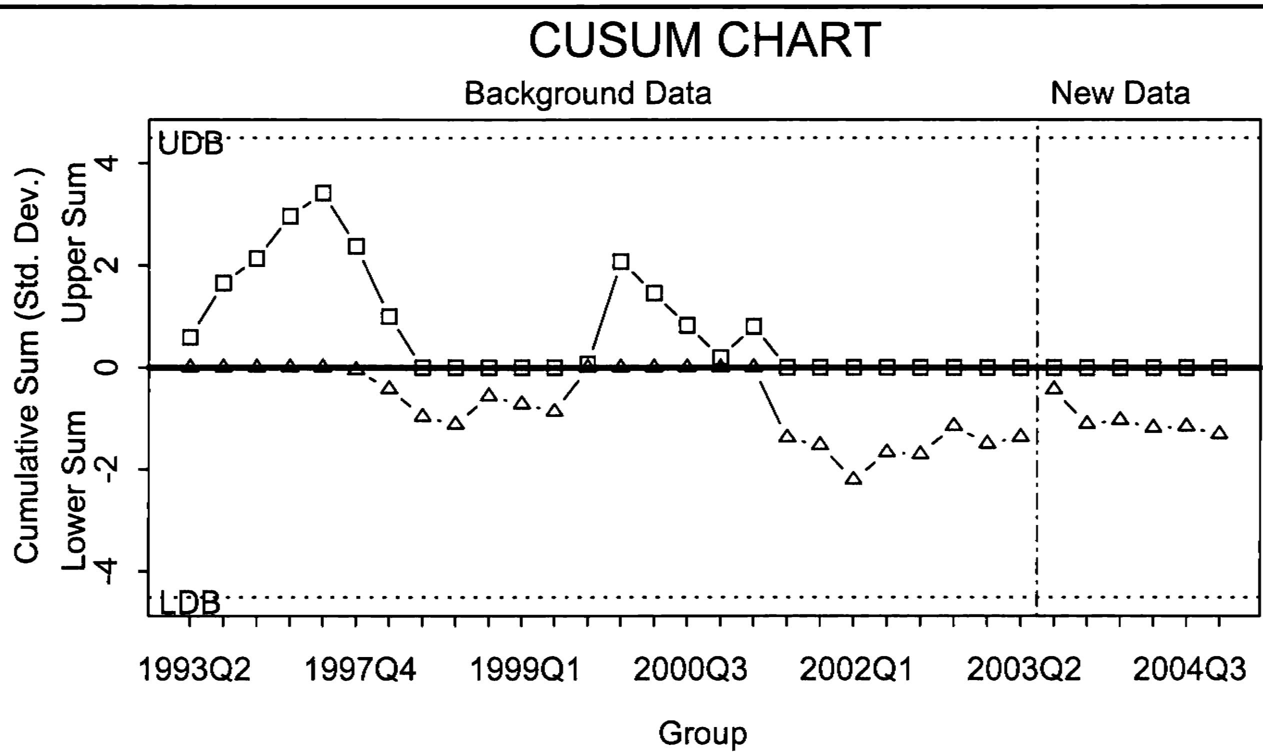


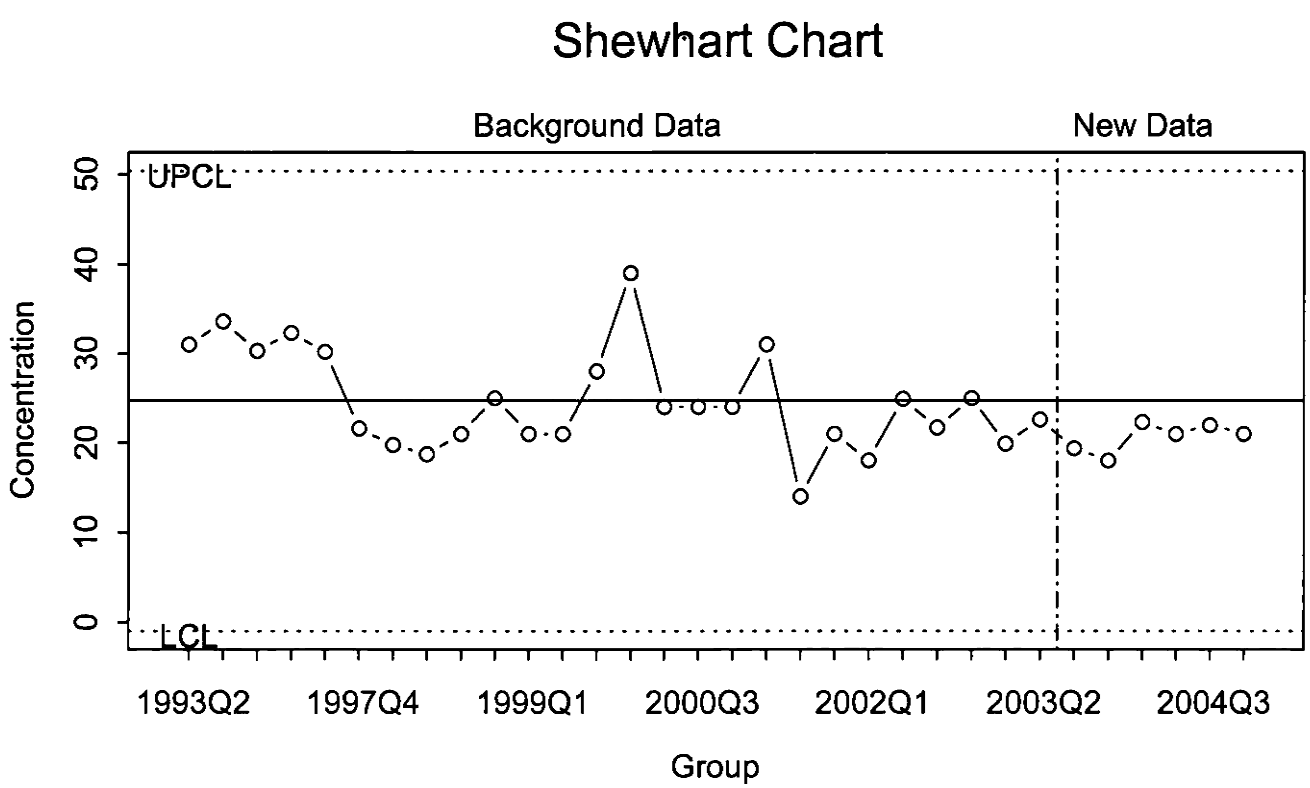
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-73D
Nitrogen, Ammonia
mg/l



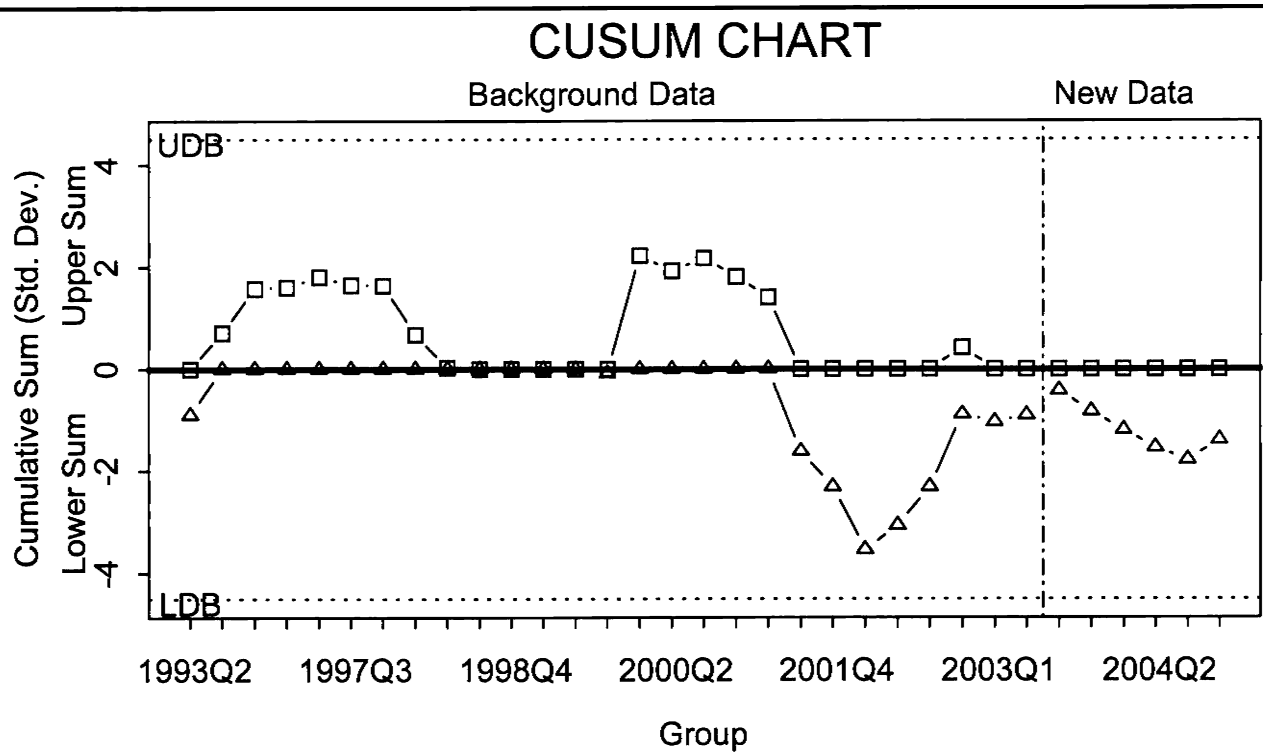


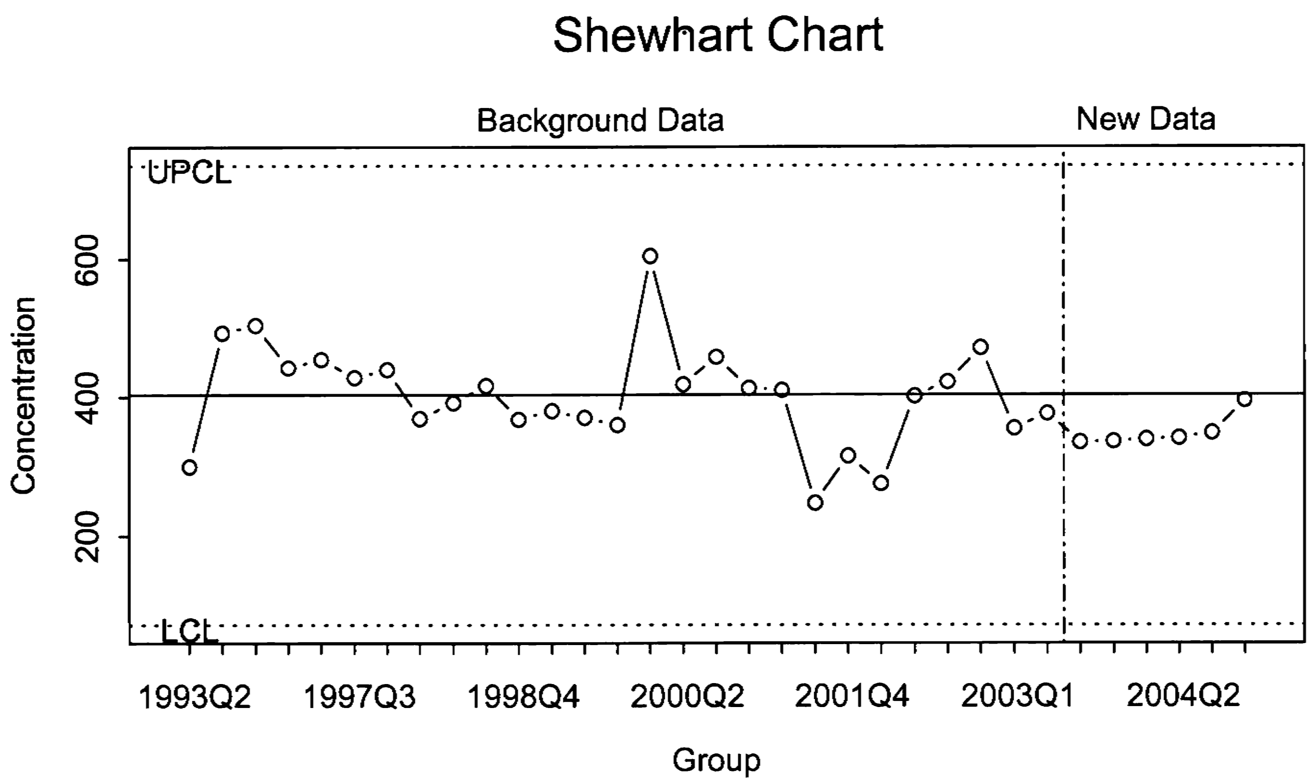
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-73D
Sodium, Dissolved
mg/l



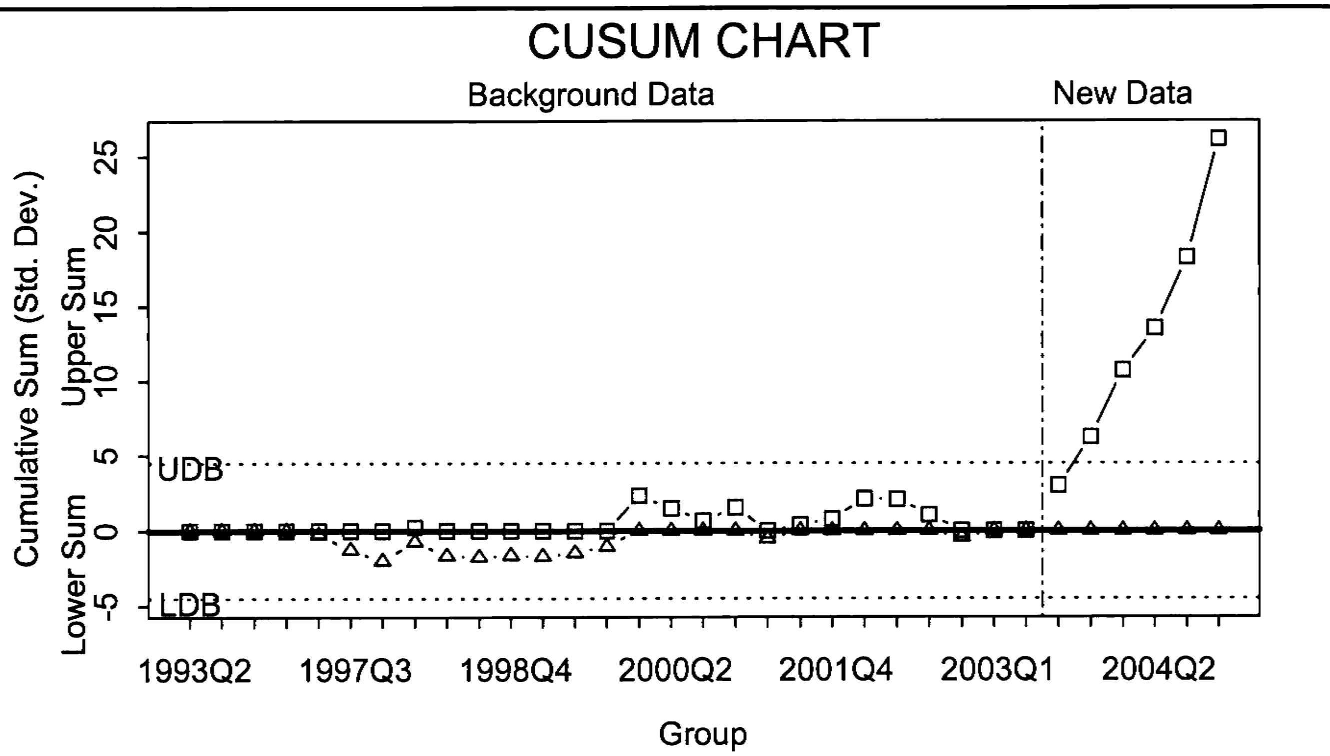


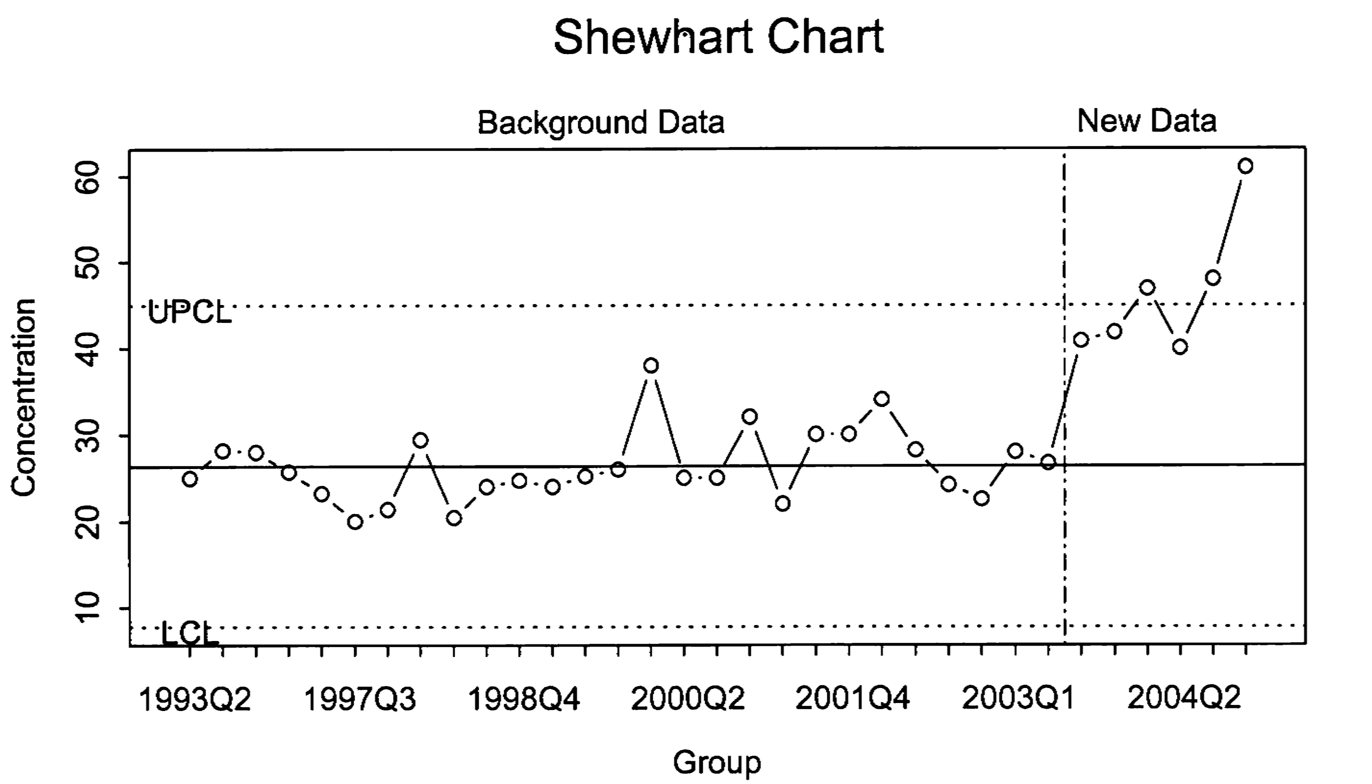
GEOMEGA

5/18/05

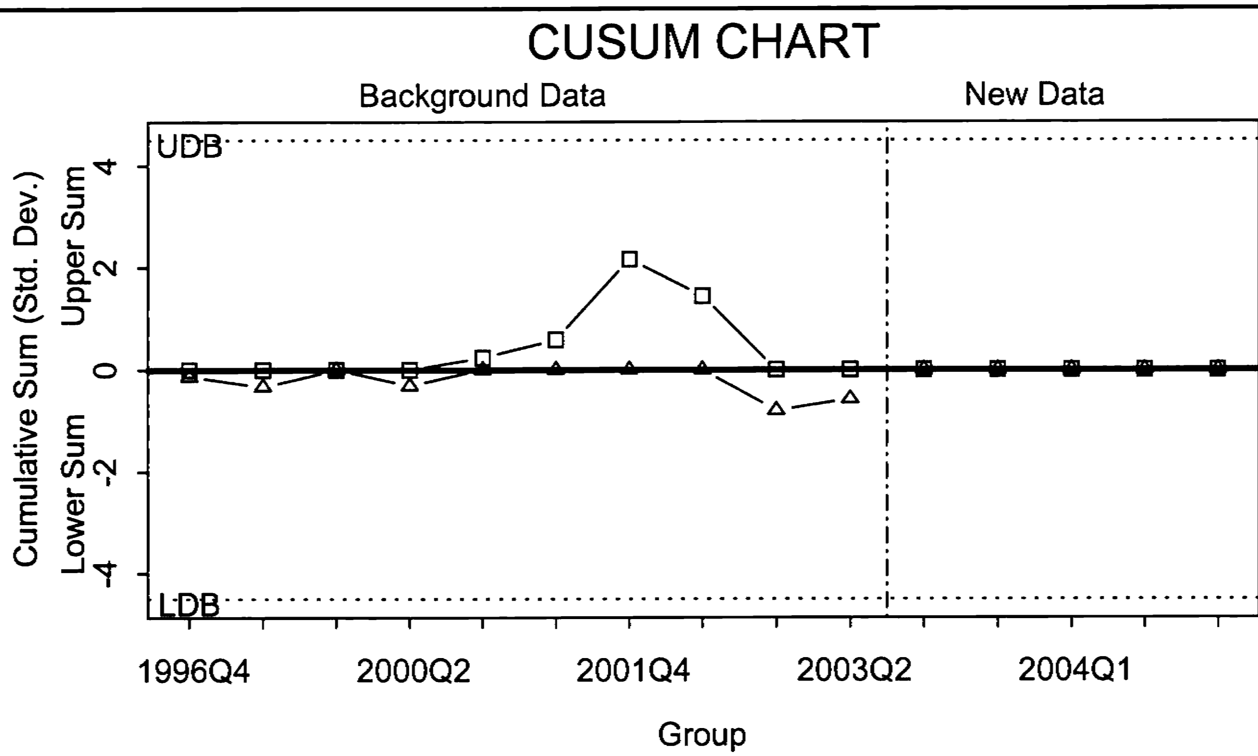
C03302C
Olin-Wilmington

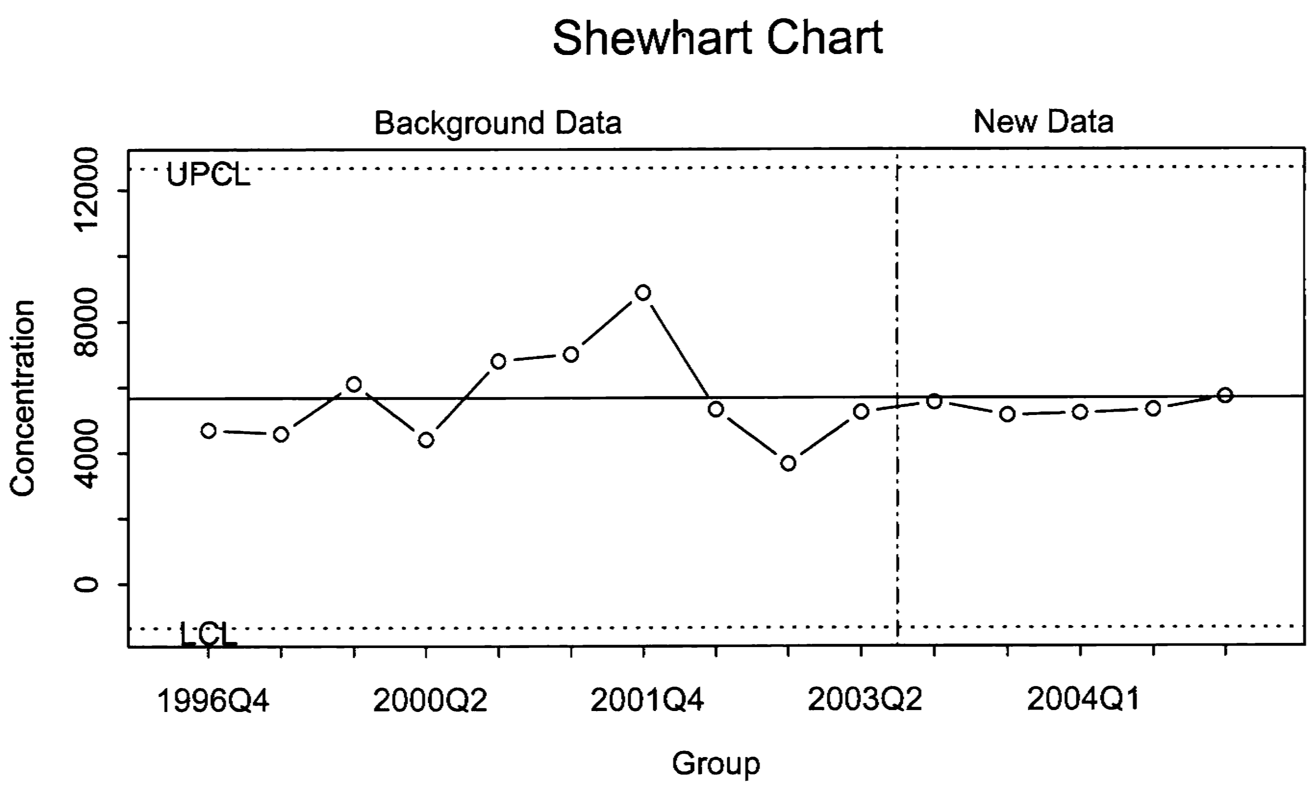
GW-73D
Specific Conductance
umhos/cm





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-73D Sulfate as SO4 mg/l	



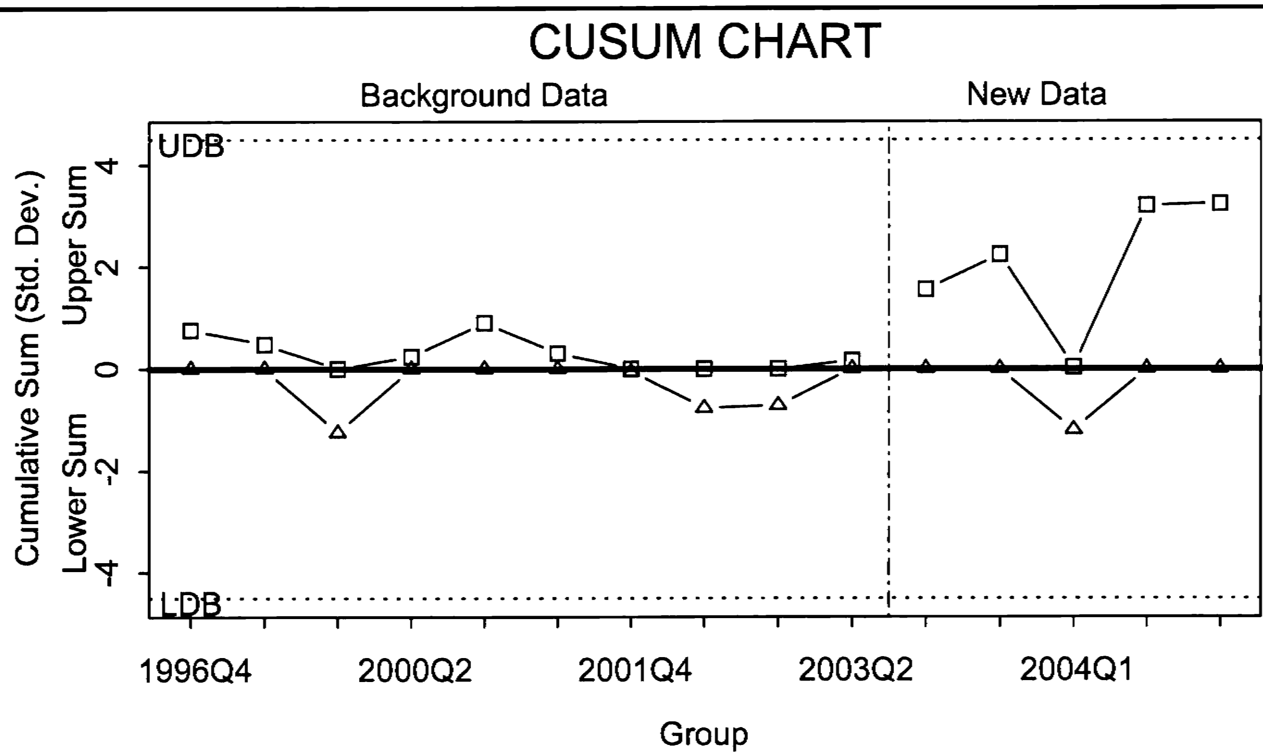


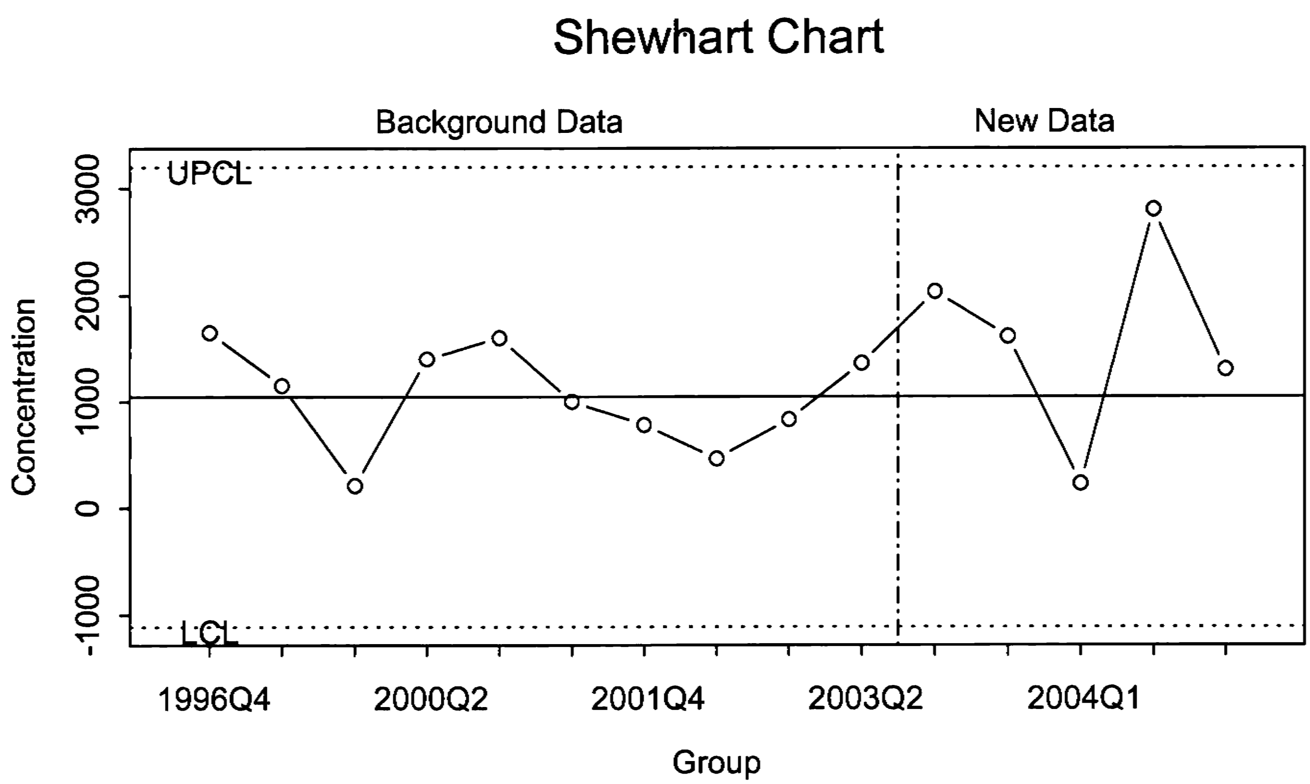
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-83D
Chloride
mg/l





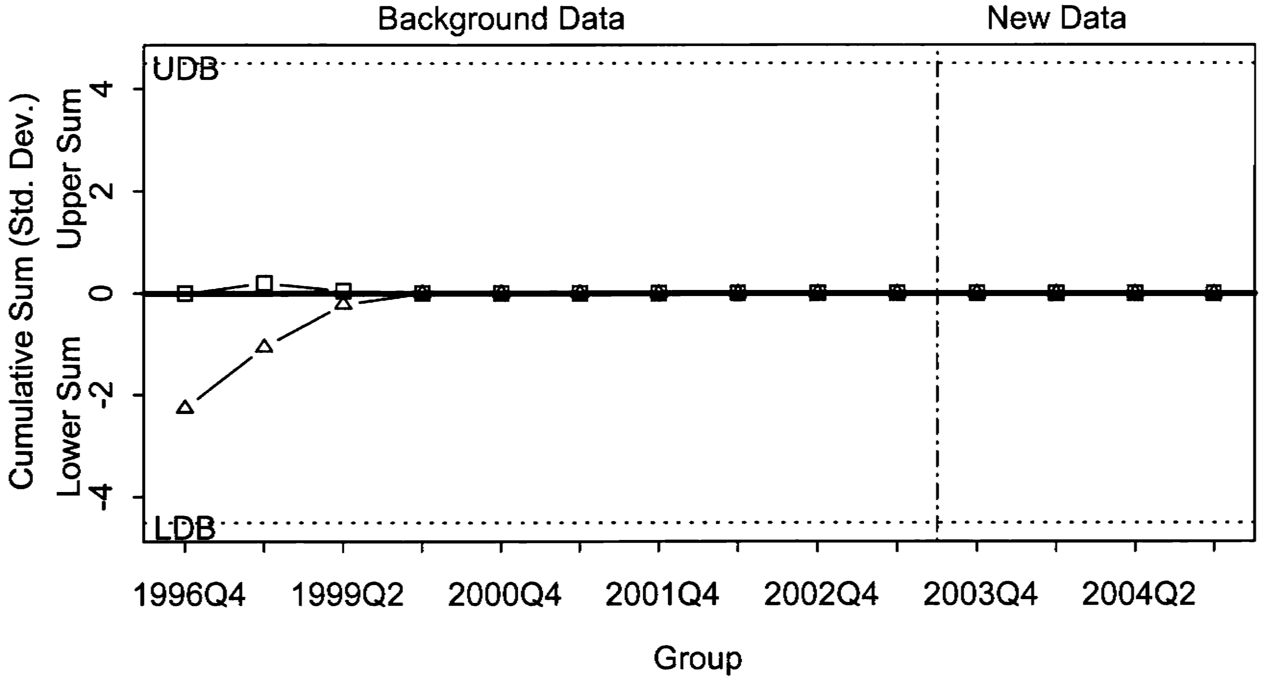
GEOMEGA

5/18/05

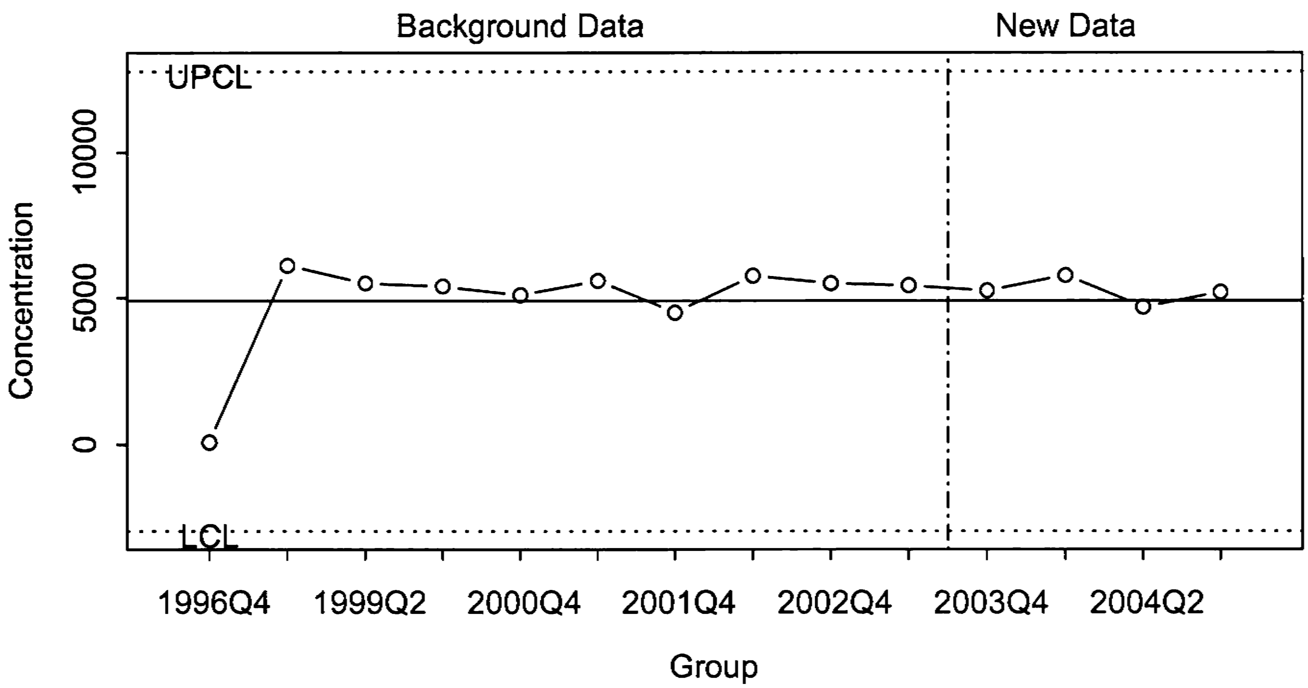
C03302C
Olin-Wilmington

GW-83D
Nitrogen, Ammonia
mg/l

CUSUM CHART



Shewhart Chart



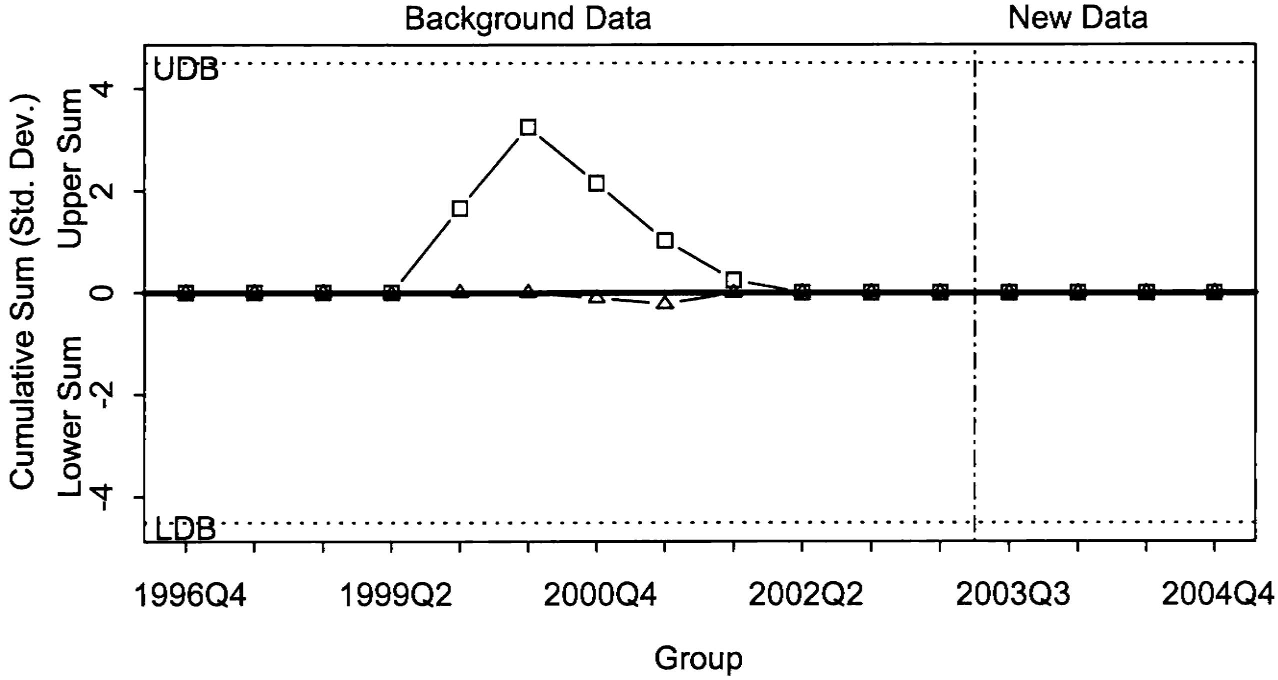
GEOMEGA

5/18/05

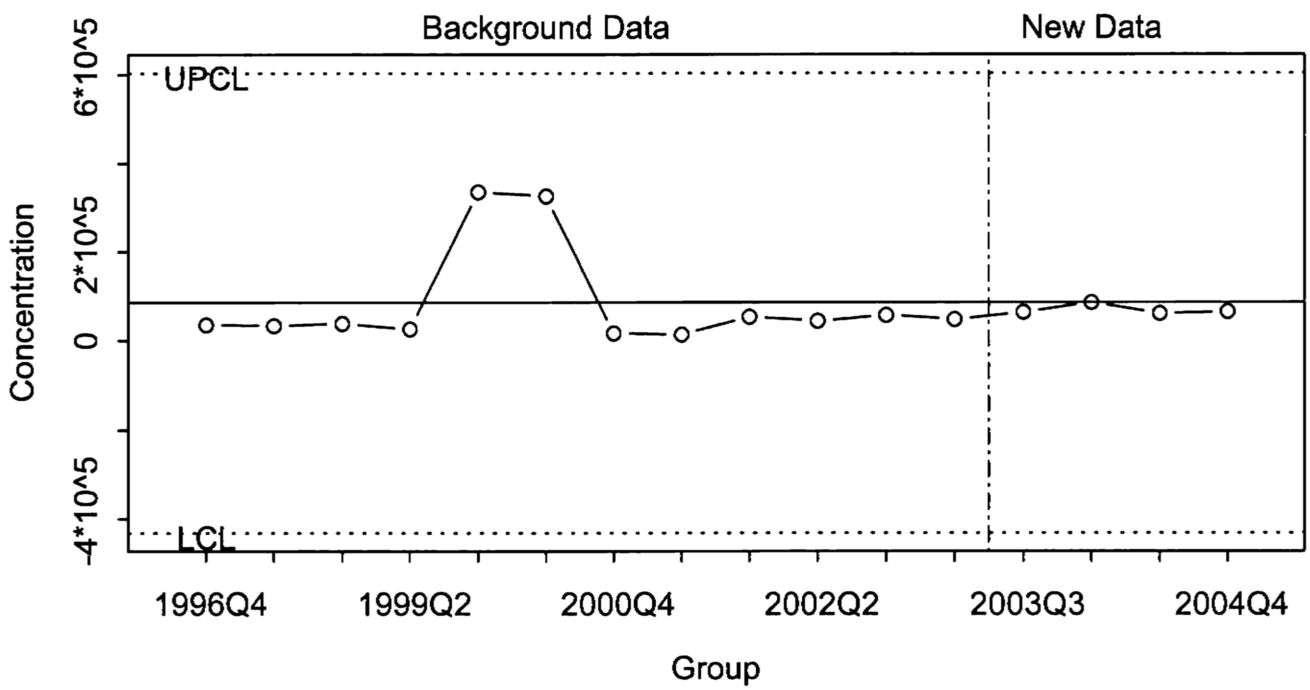
C03302C
Olin-Wilmington

GW-83D
Sodium, Dissolved
mg/l

CUSUM CHART



Shewhart Chart

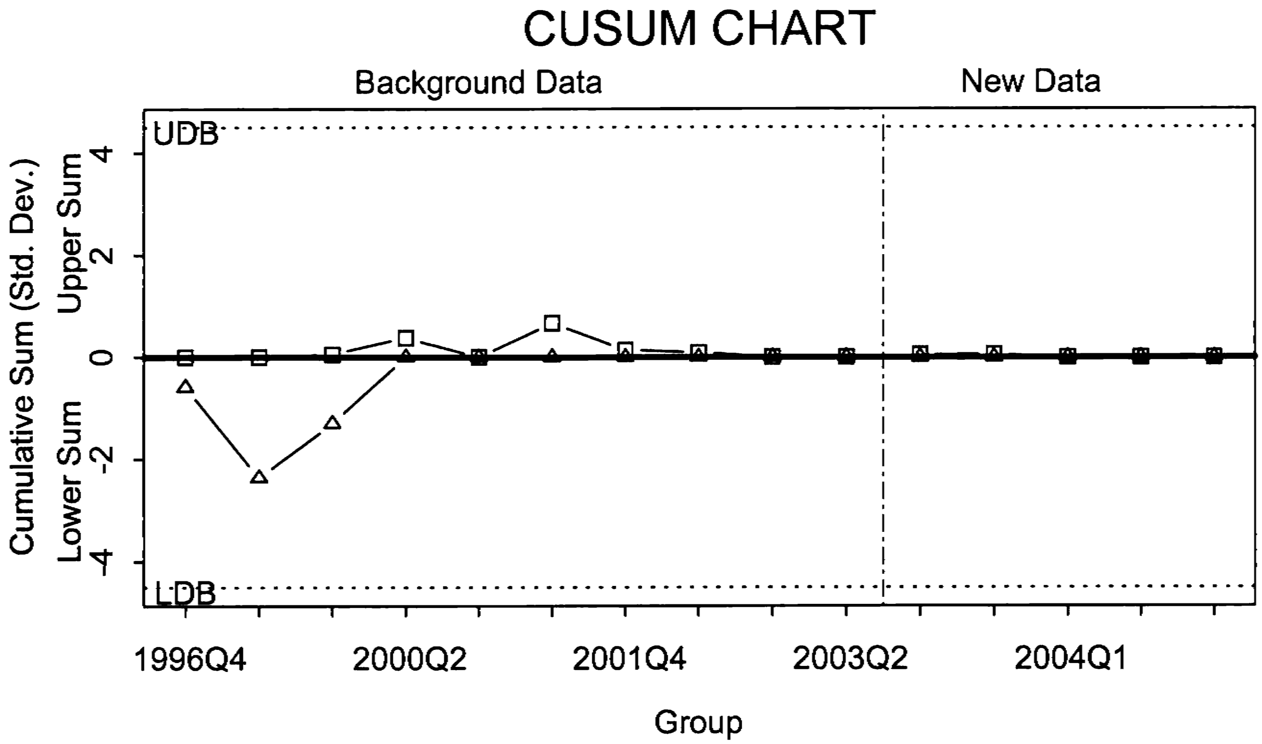


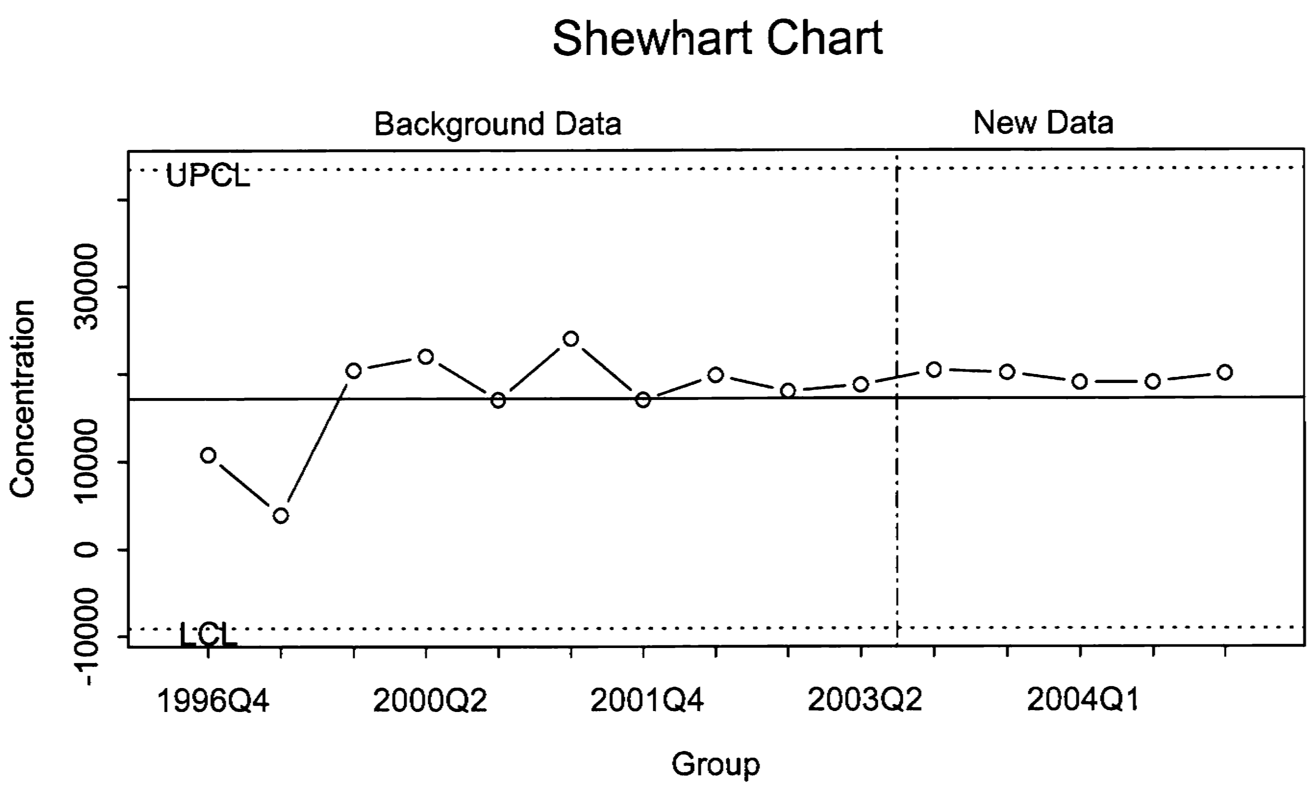
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

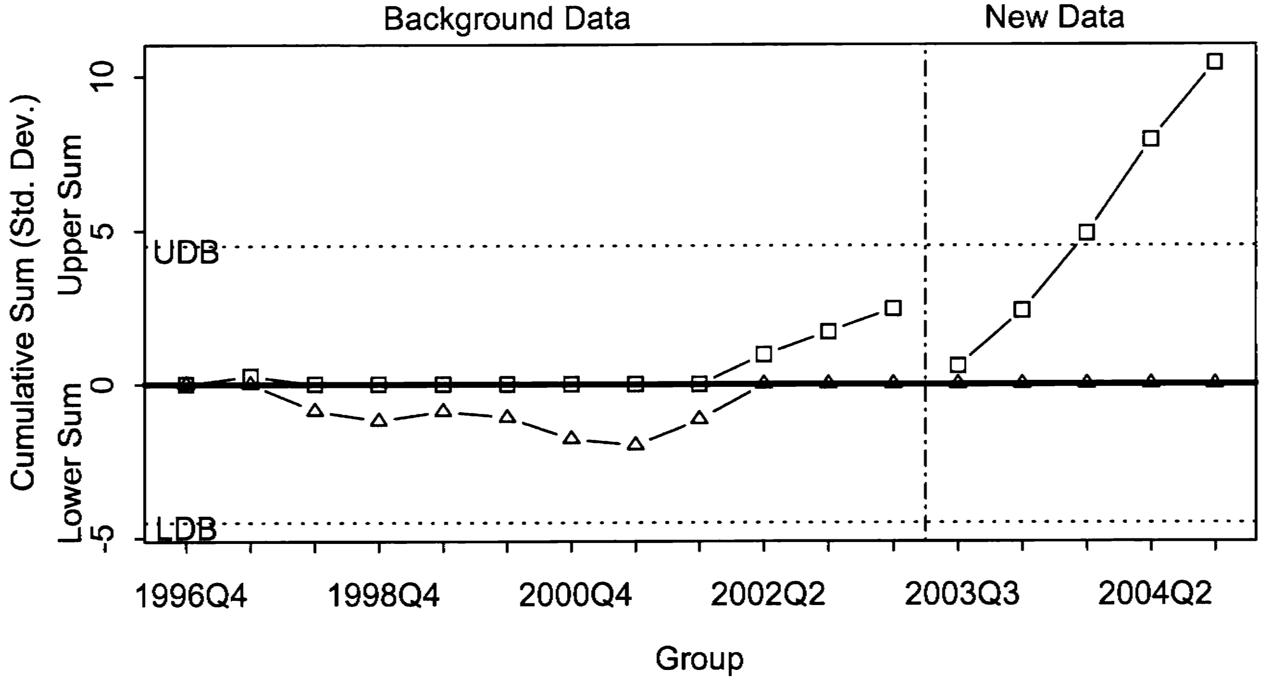
GW-83D
Specific Conductance
umhos/cm





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-83D Sulfate as SO4 mg/l	

CUSUM CHART



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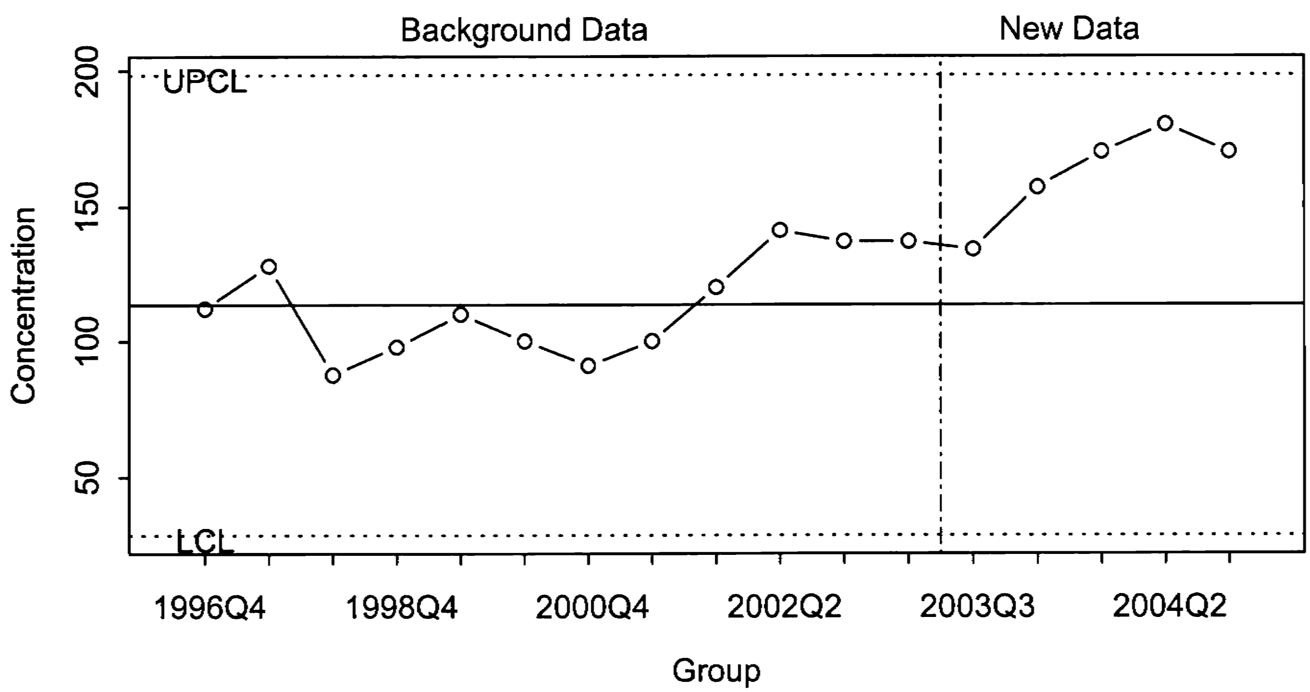
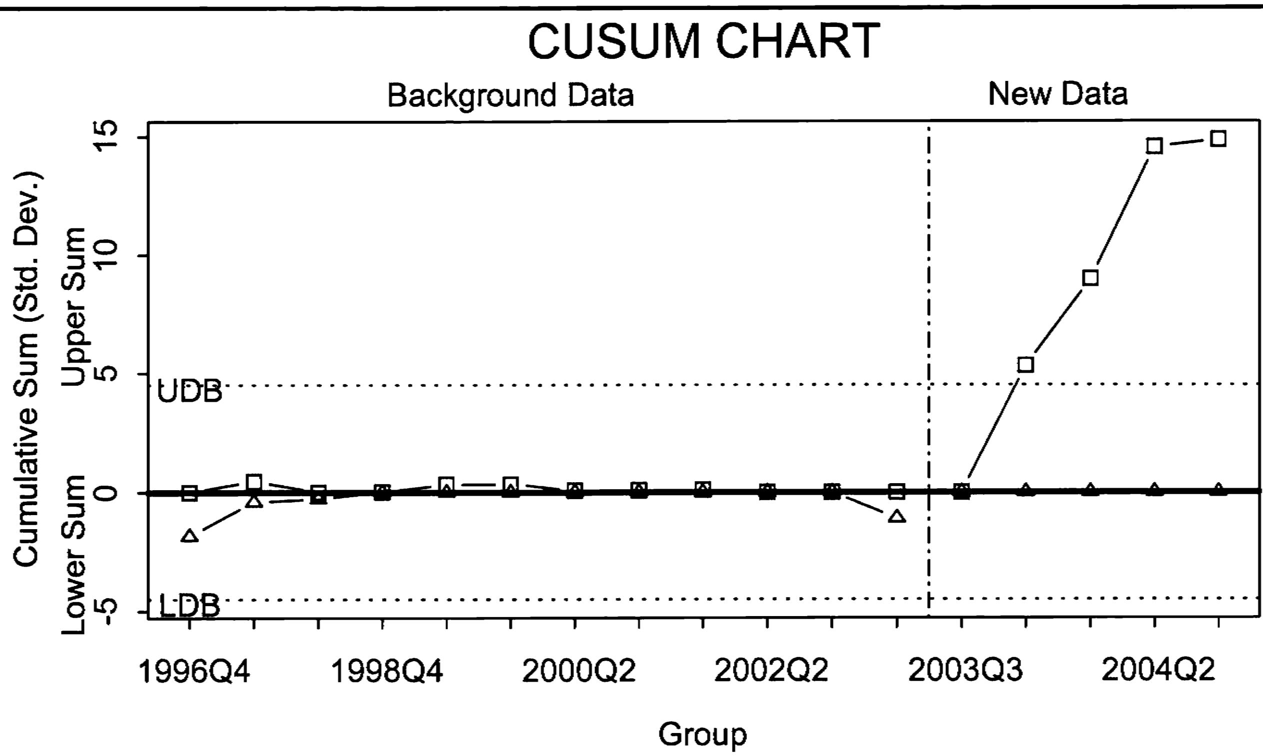
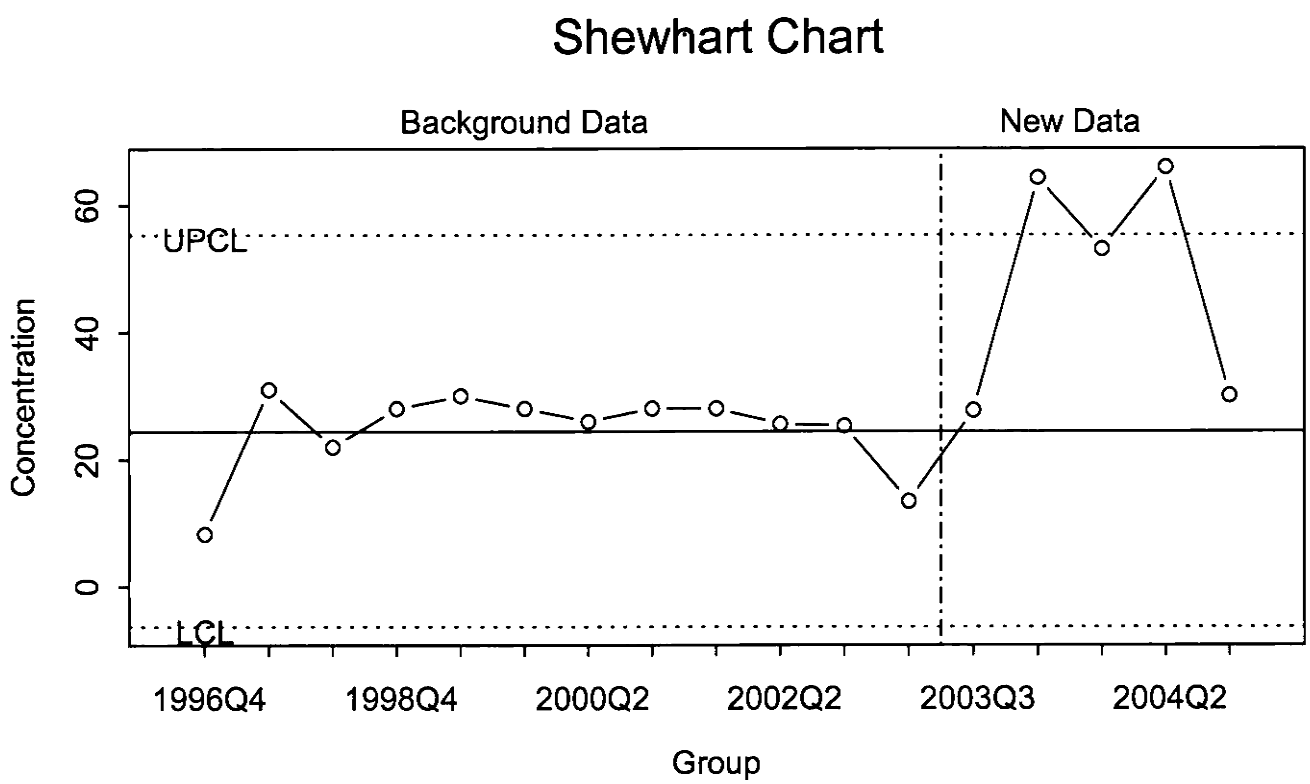


GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-83M Chloride mg/l	



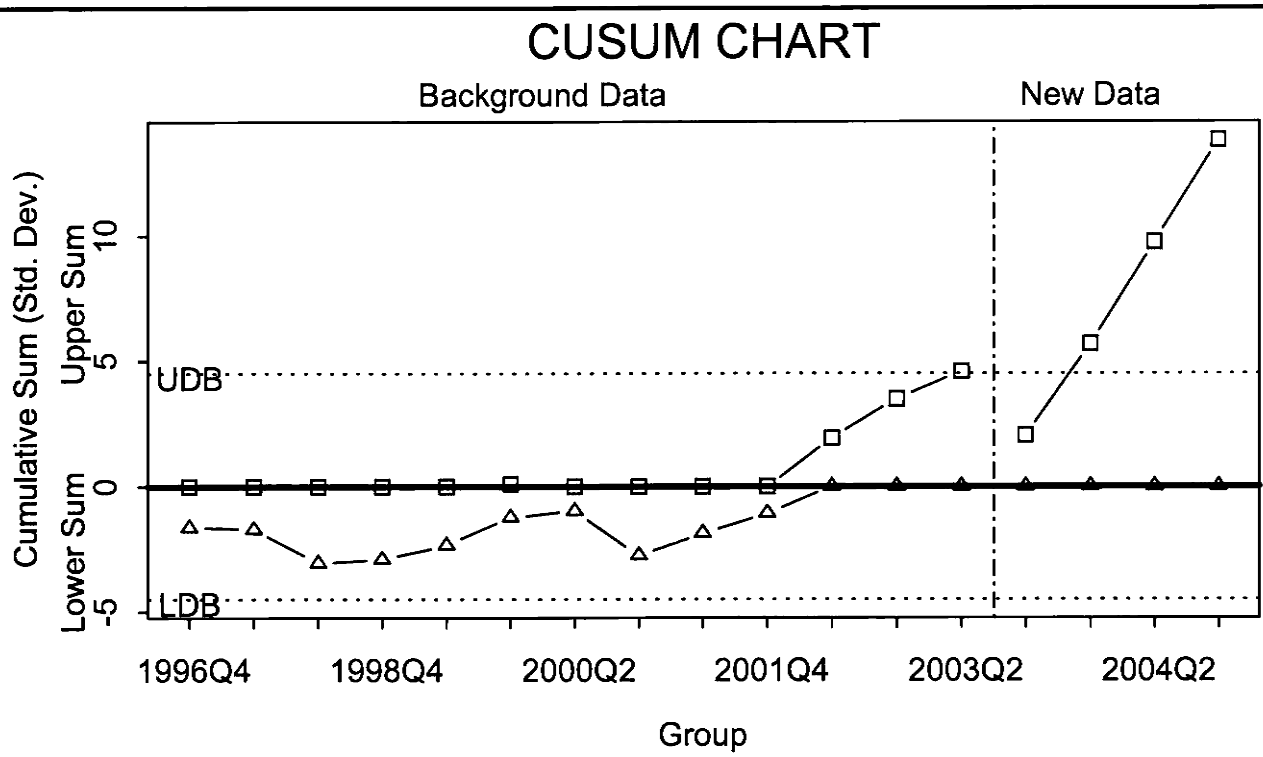


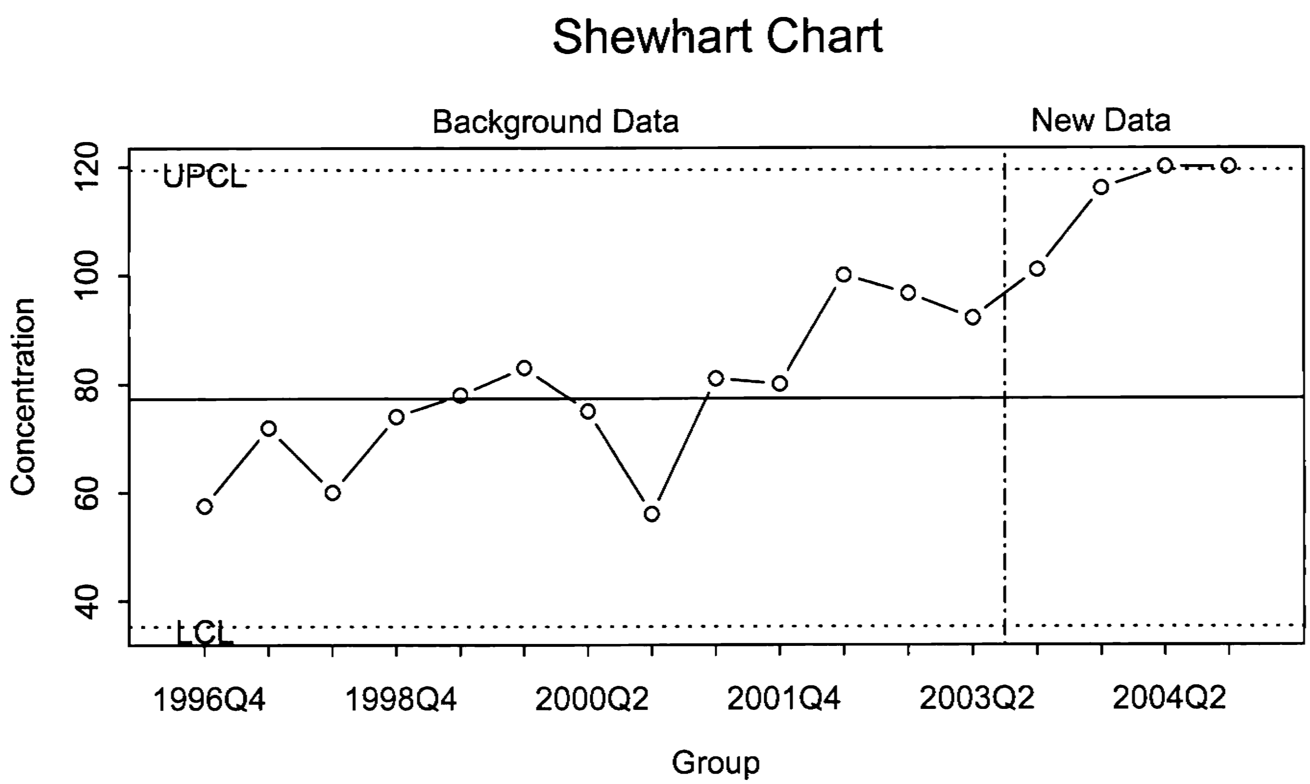
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-83M
Nitrogen, Ammonia
mg/l



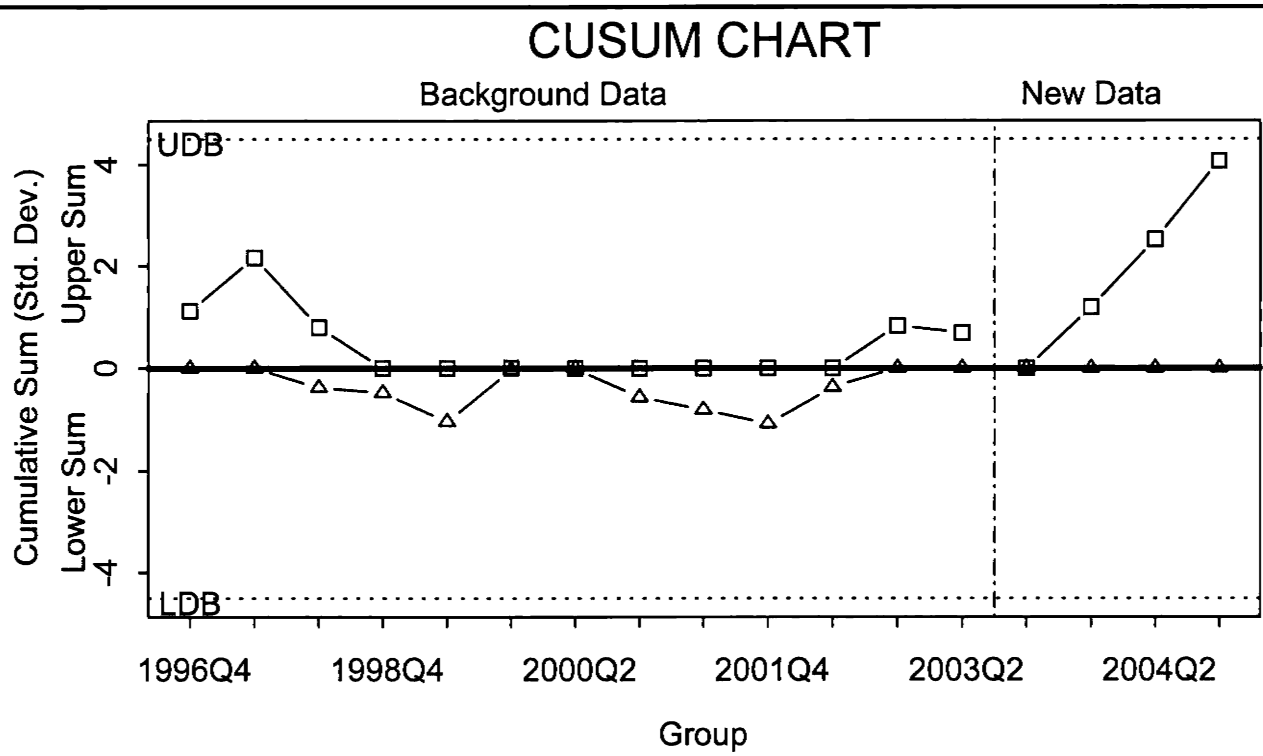


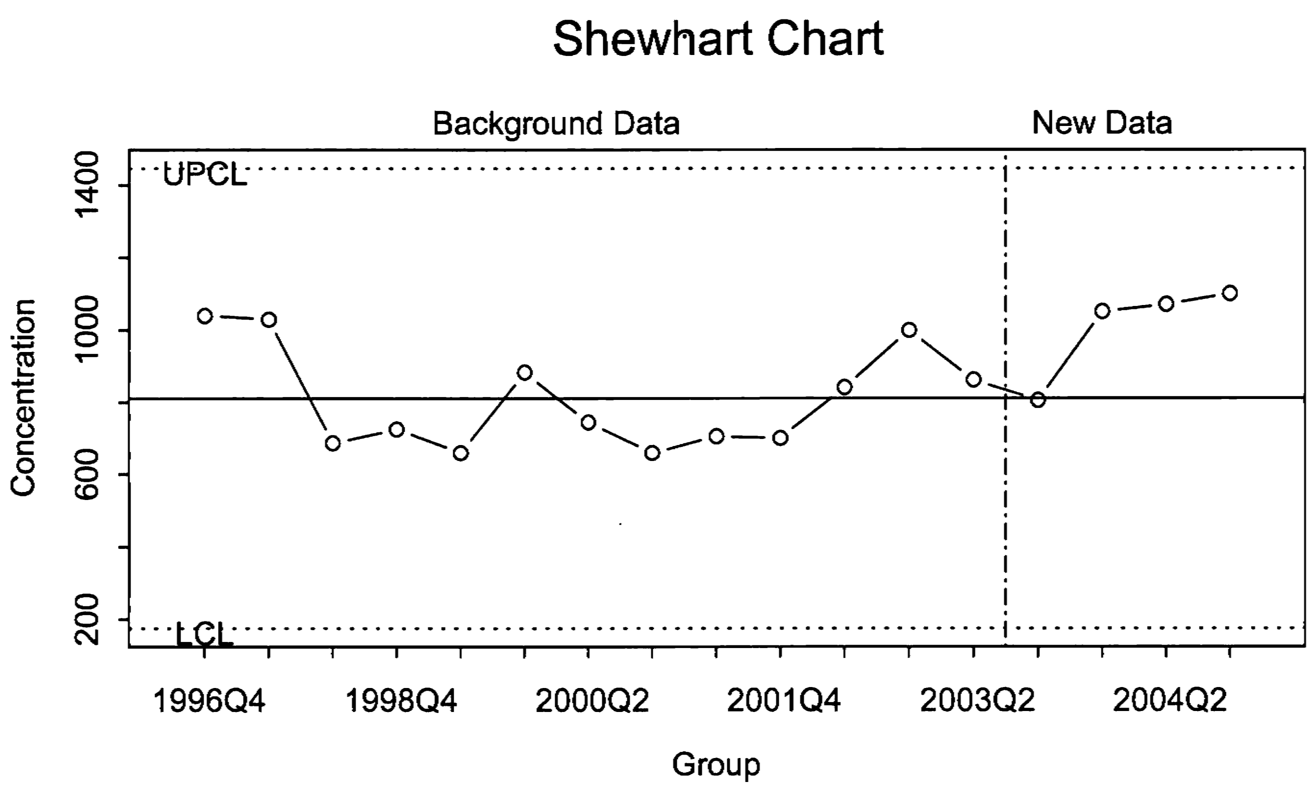
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-83M
Sodium, Dissolved
mg/l





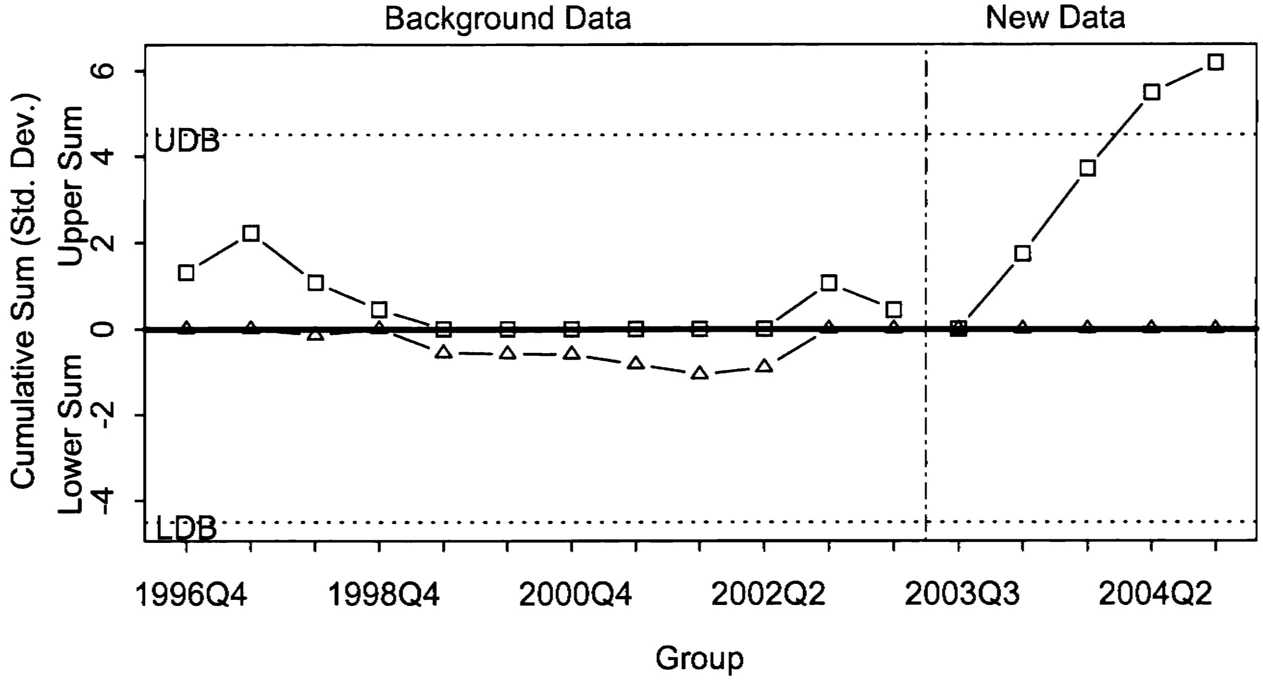
GEOMEGA

5/18/05

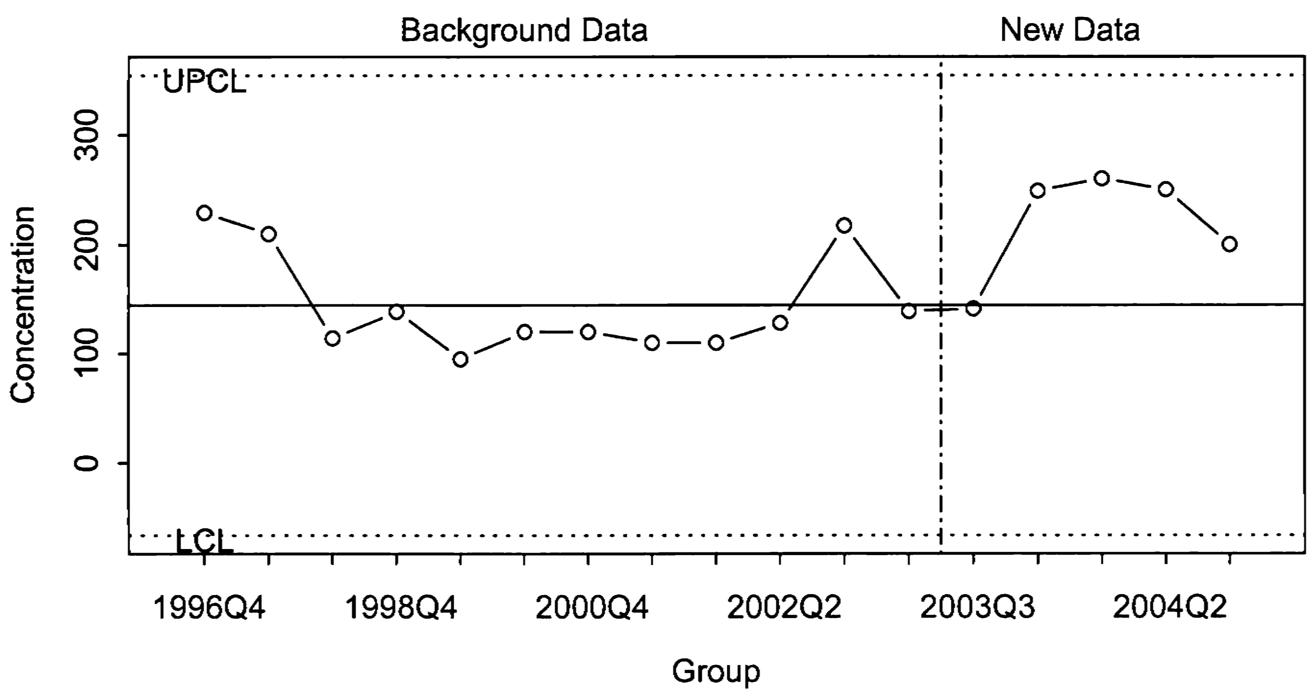
C03302C
Olin-Wilmington

GW-83M
Specific Conductance
umhos/cm

CUSUM CHART



Shewhart Chart

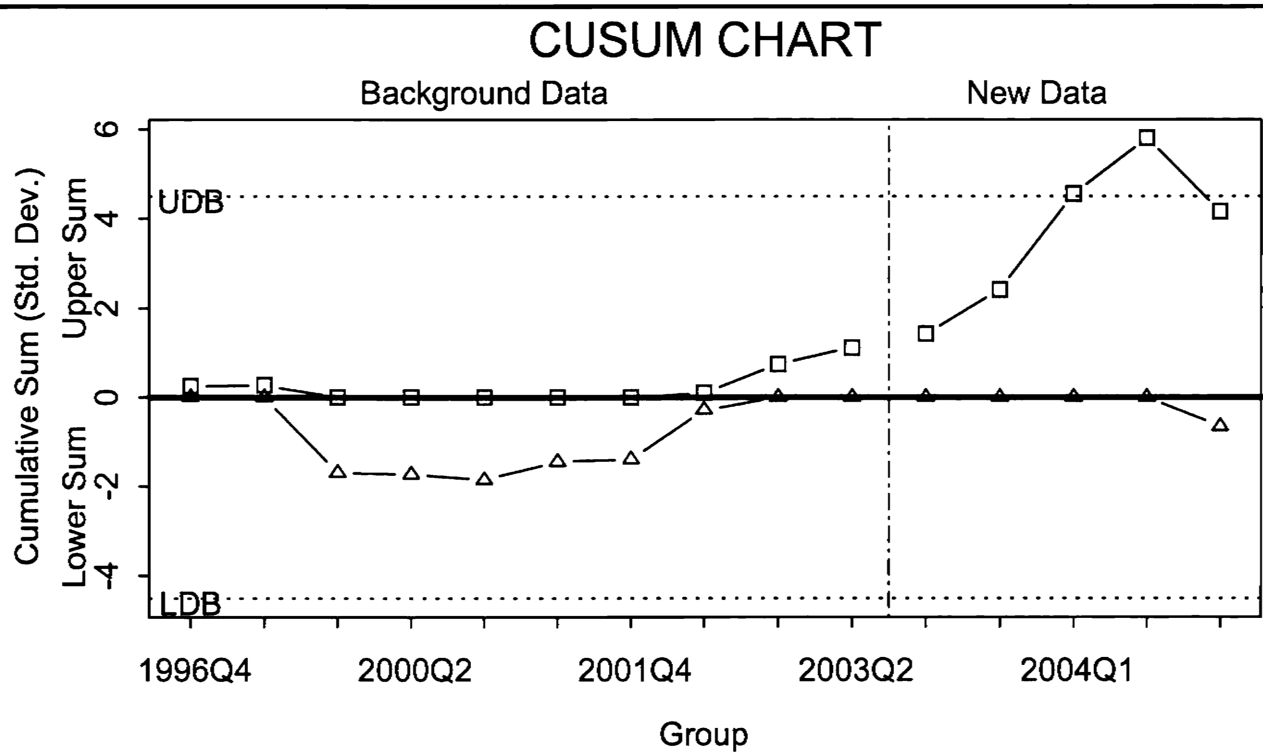


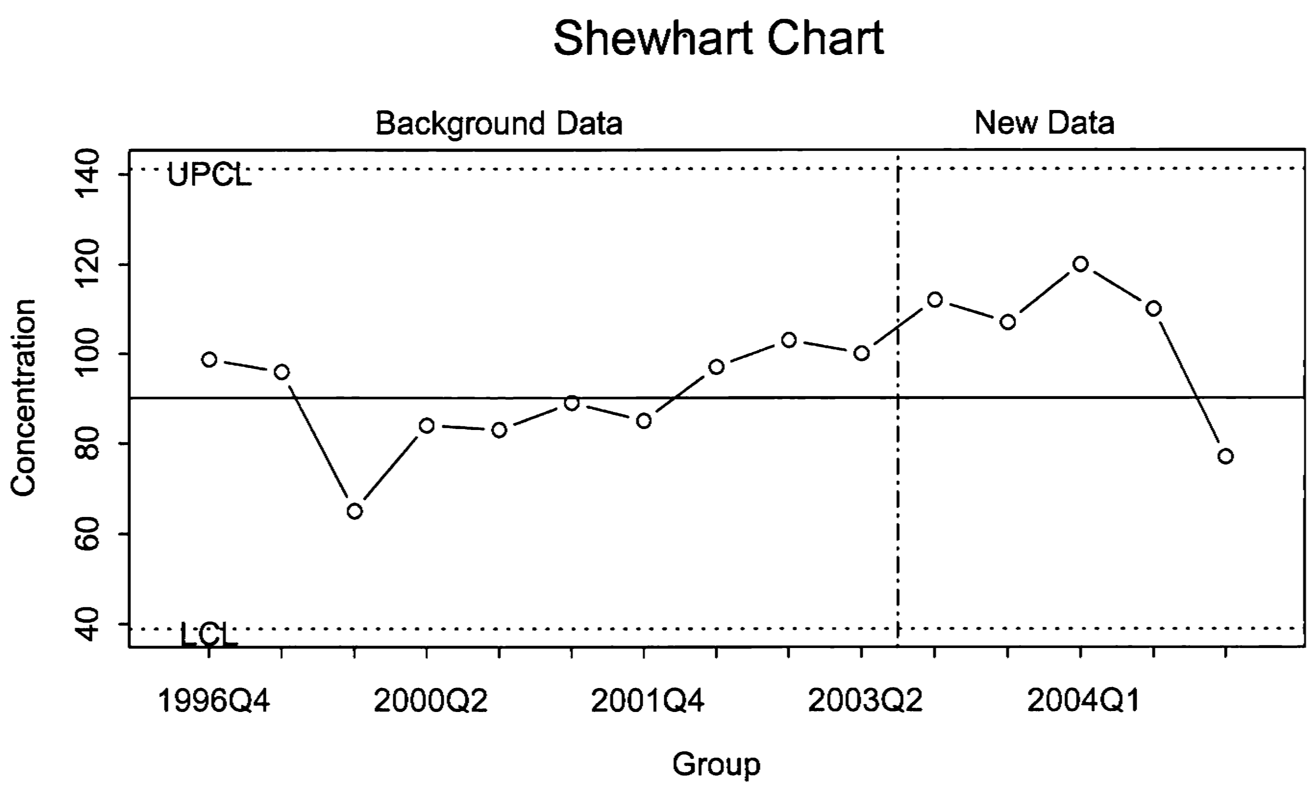
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-83M
Sulfate as SO4
mg/l



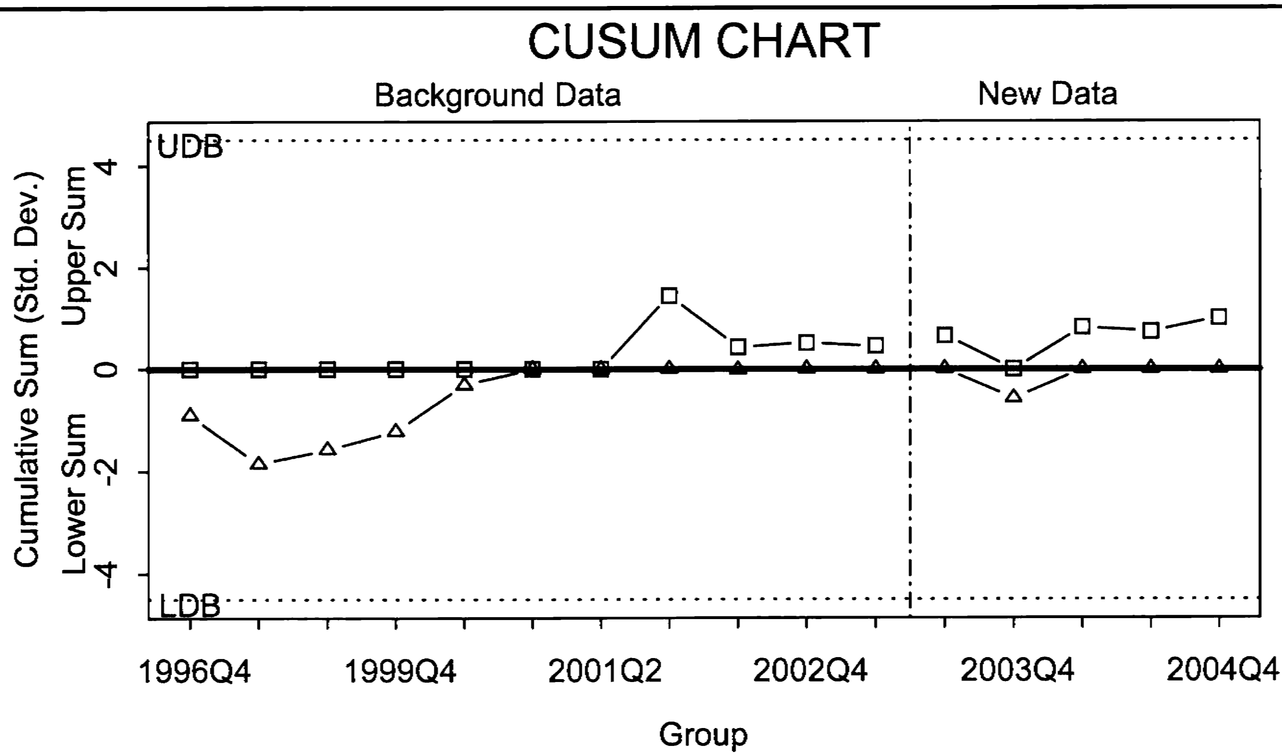


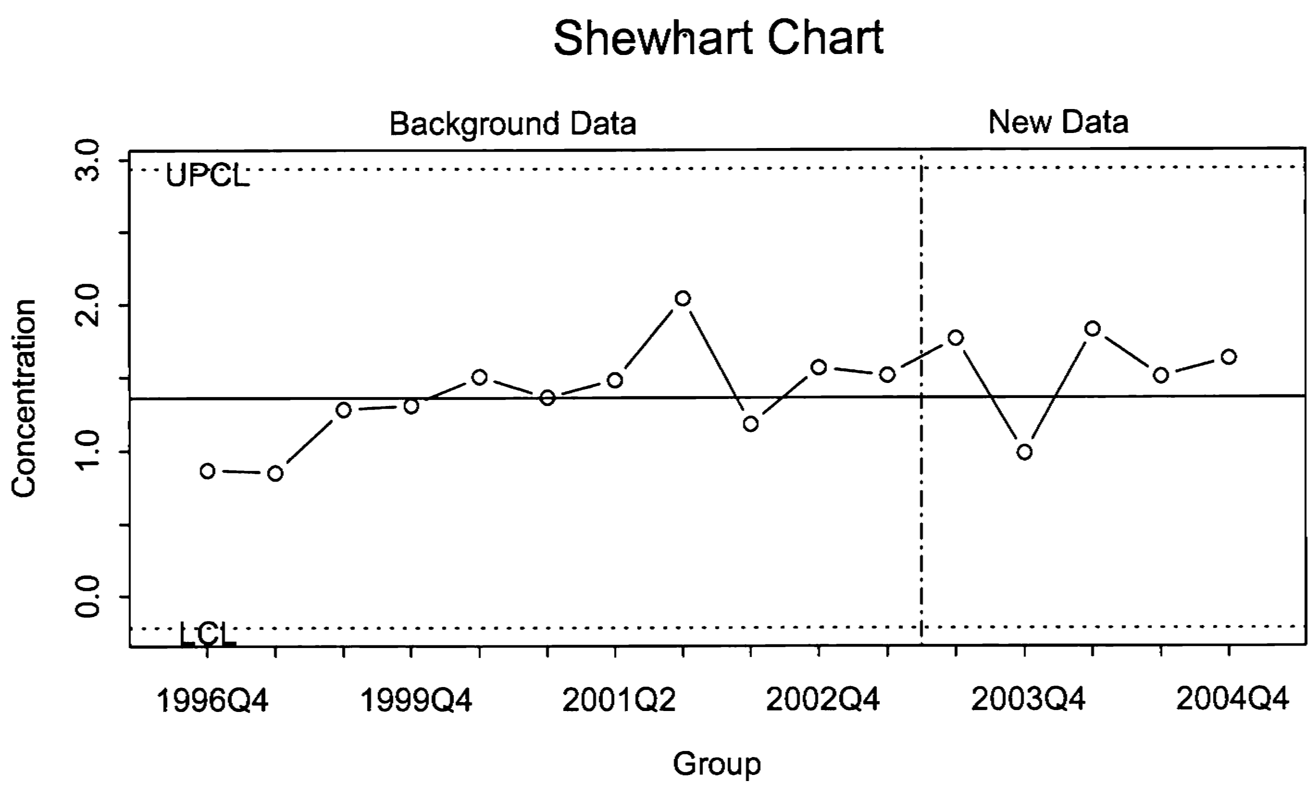
GEOMEGA

5/18/05

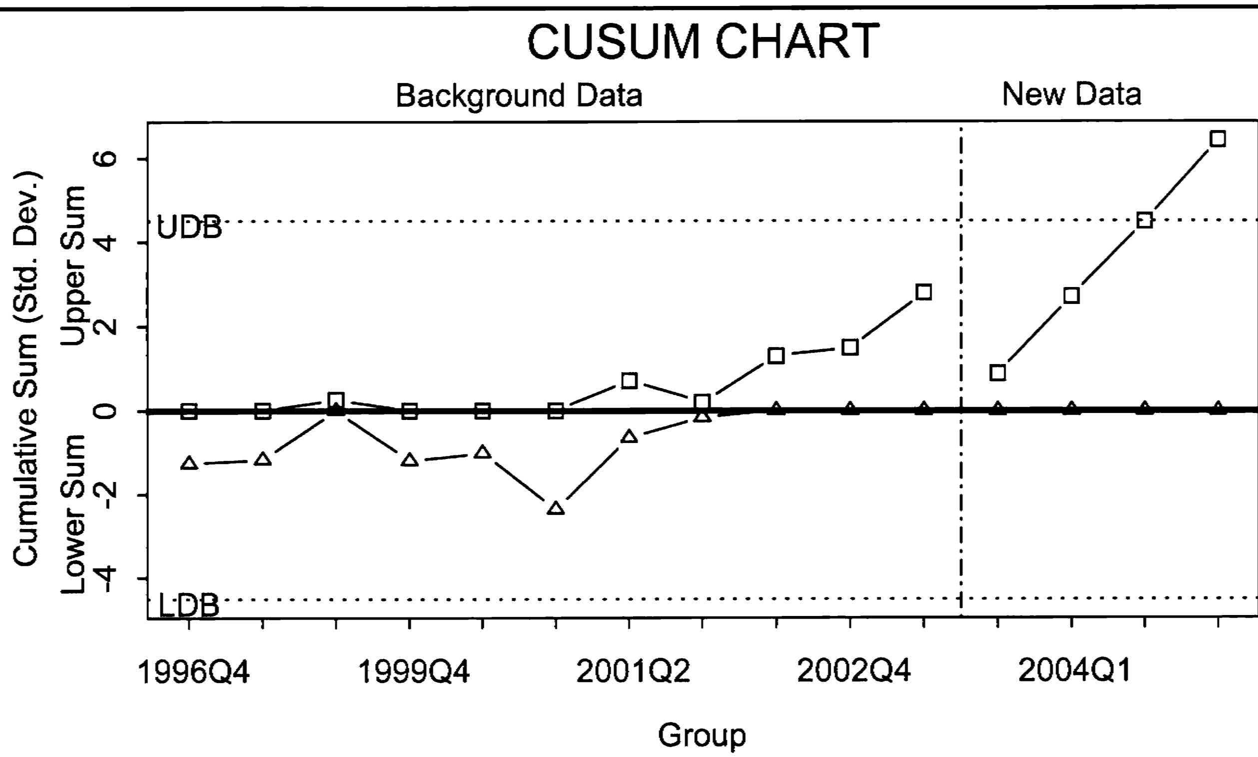
C03302C
Olin-Wilmington

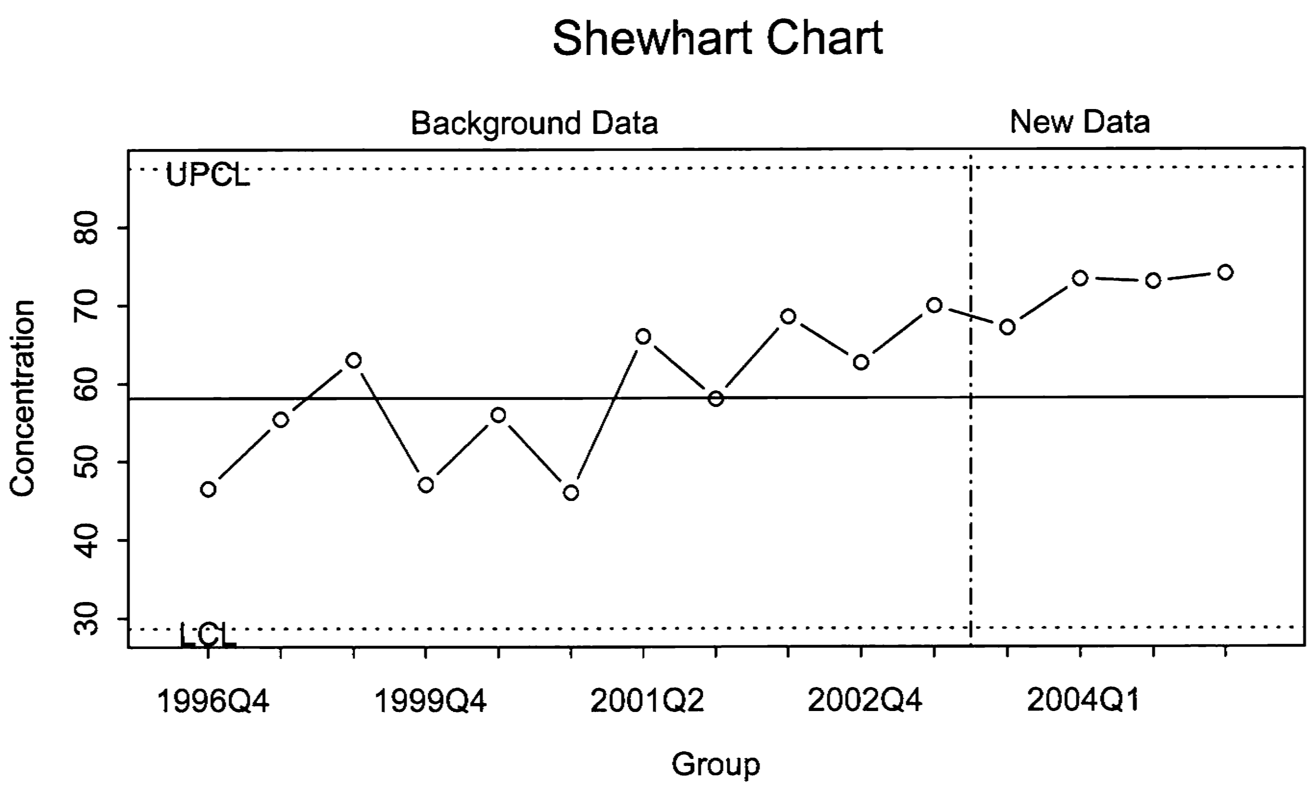
GW-83S
Chloride
mg/l





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-83S Nitrogen, Ammonia Log(mg/l)	



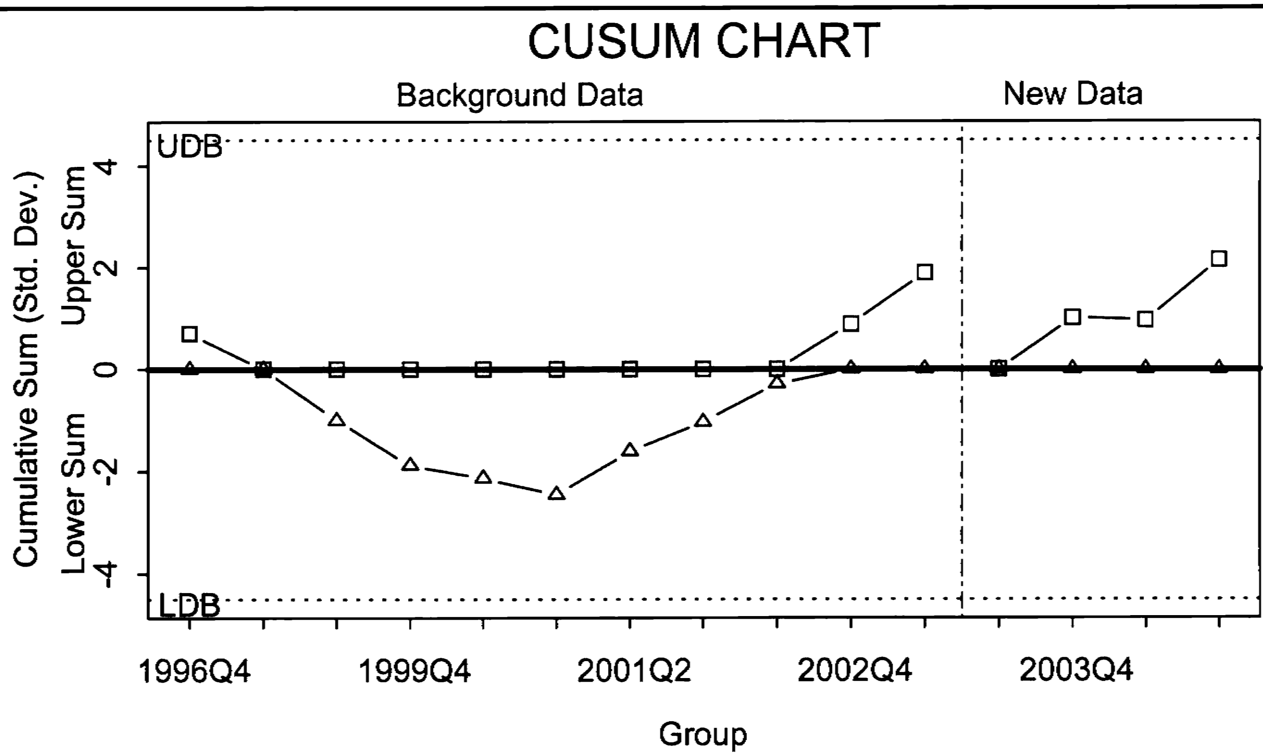


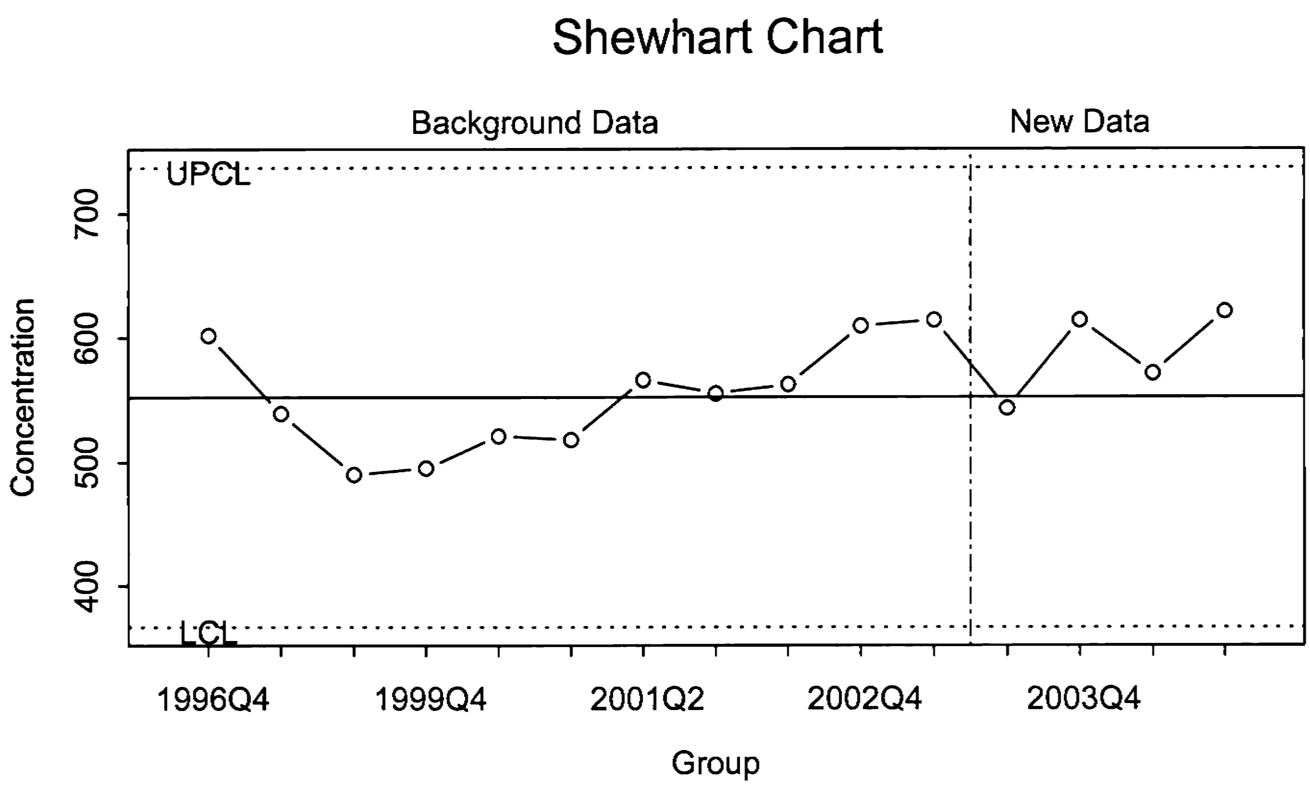
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-83S
Sodium, Dissolved
mg/l



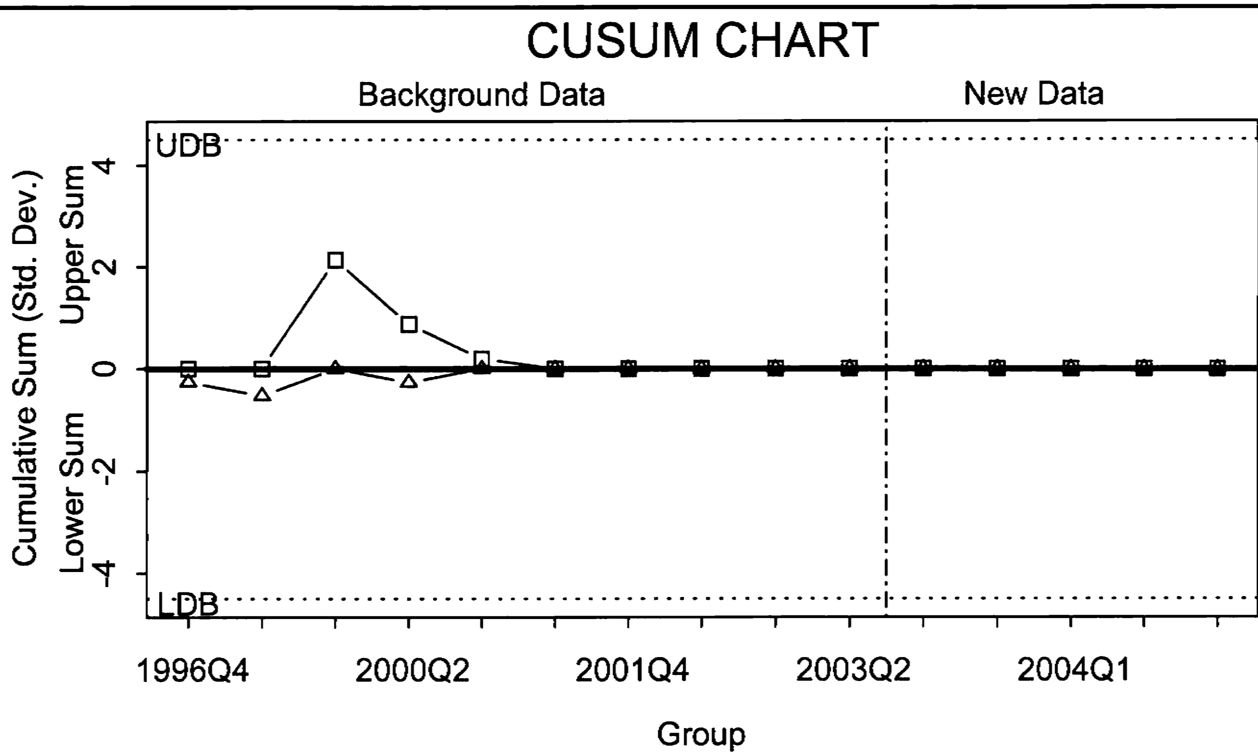


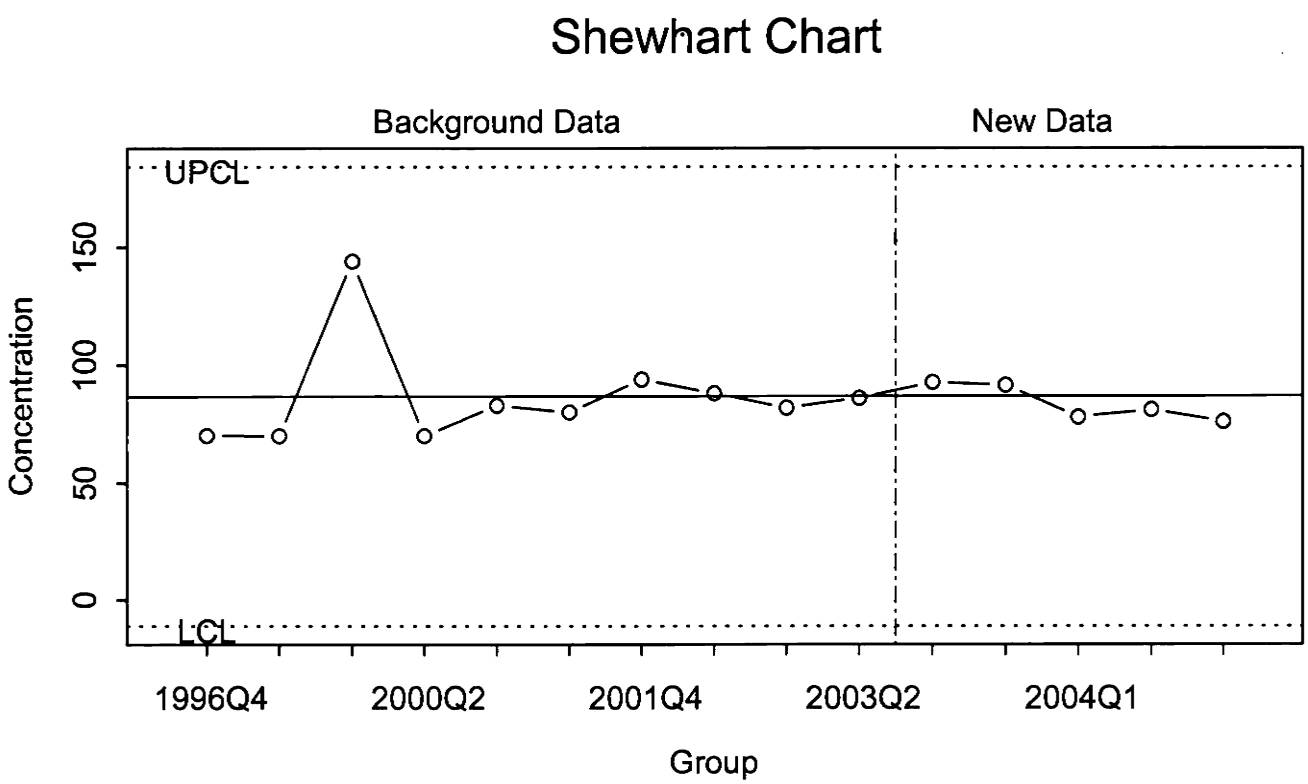
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-83S
Specific Conductance
umhos/cm





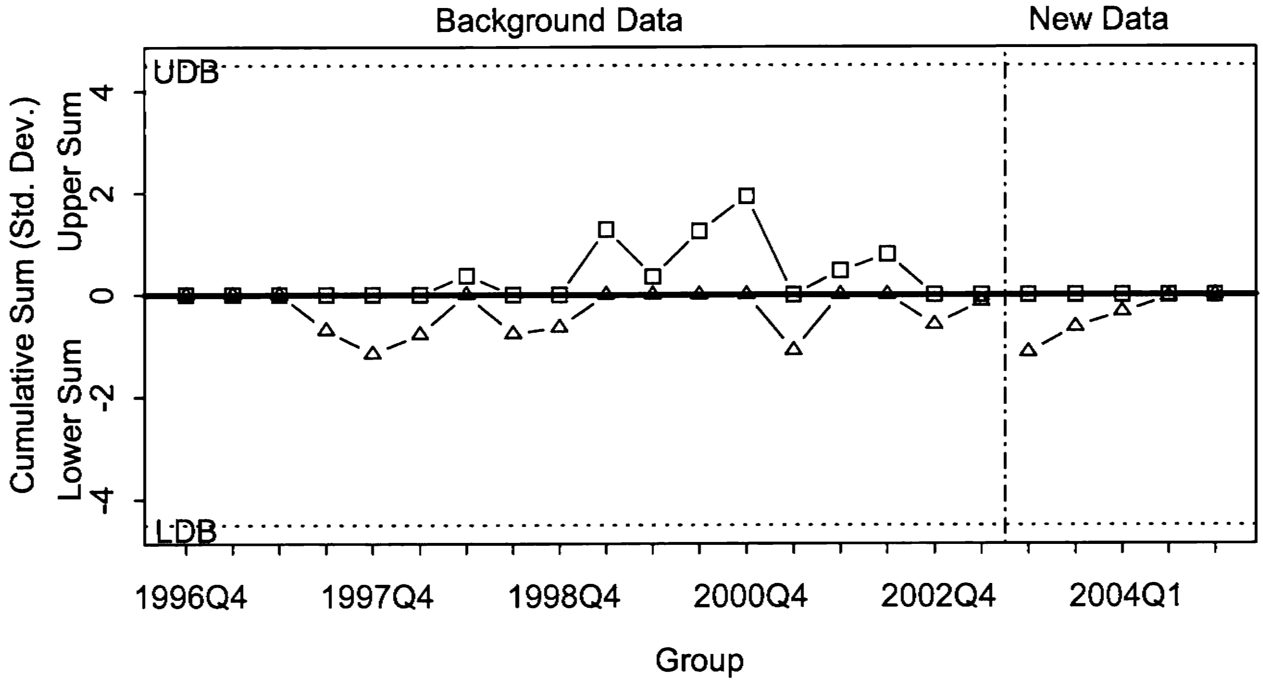
GEOMEGA

5/18/05

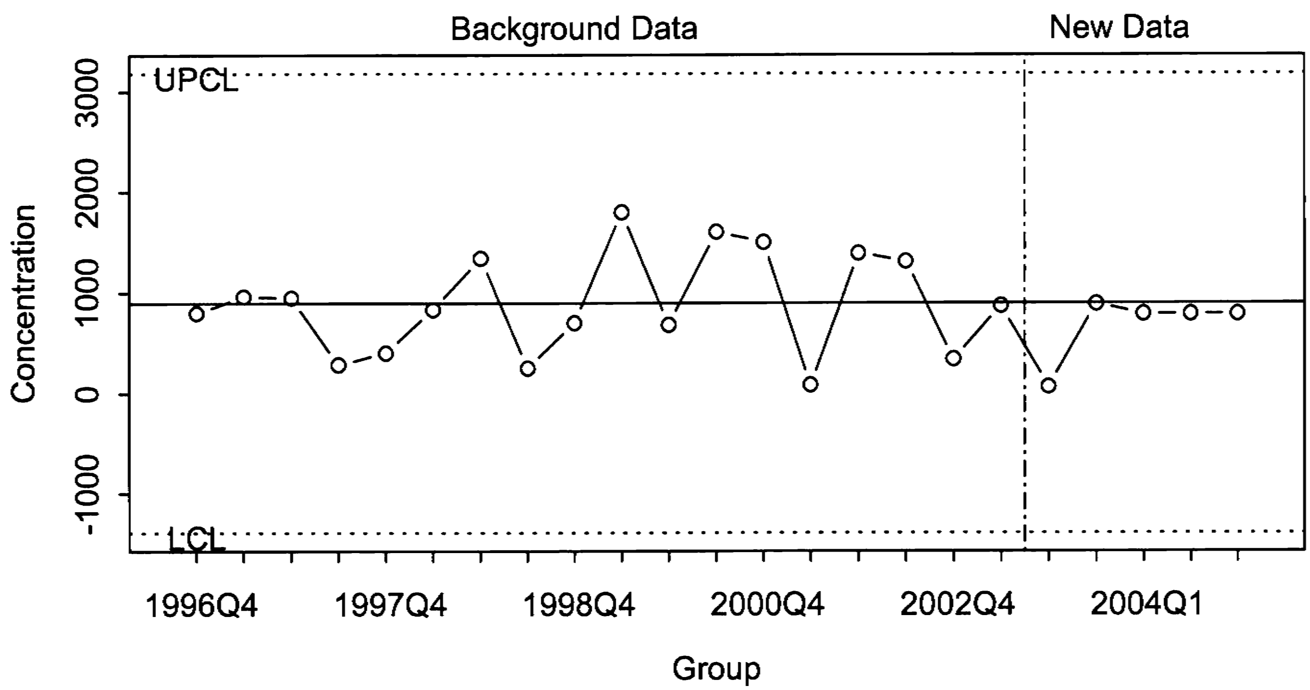
C03302C
Olin-Wilmington

GW-83S
Sulfate as SO4
mg/l

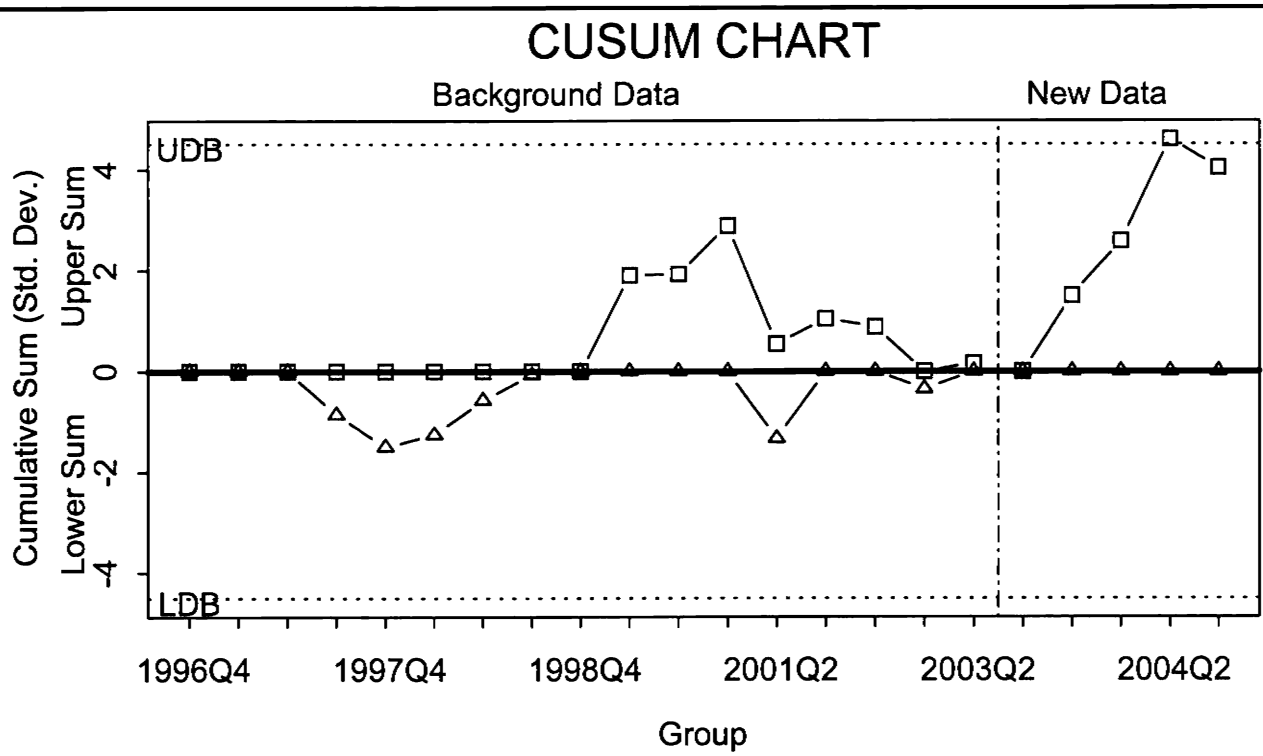
CUSUM CHART

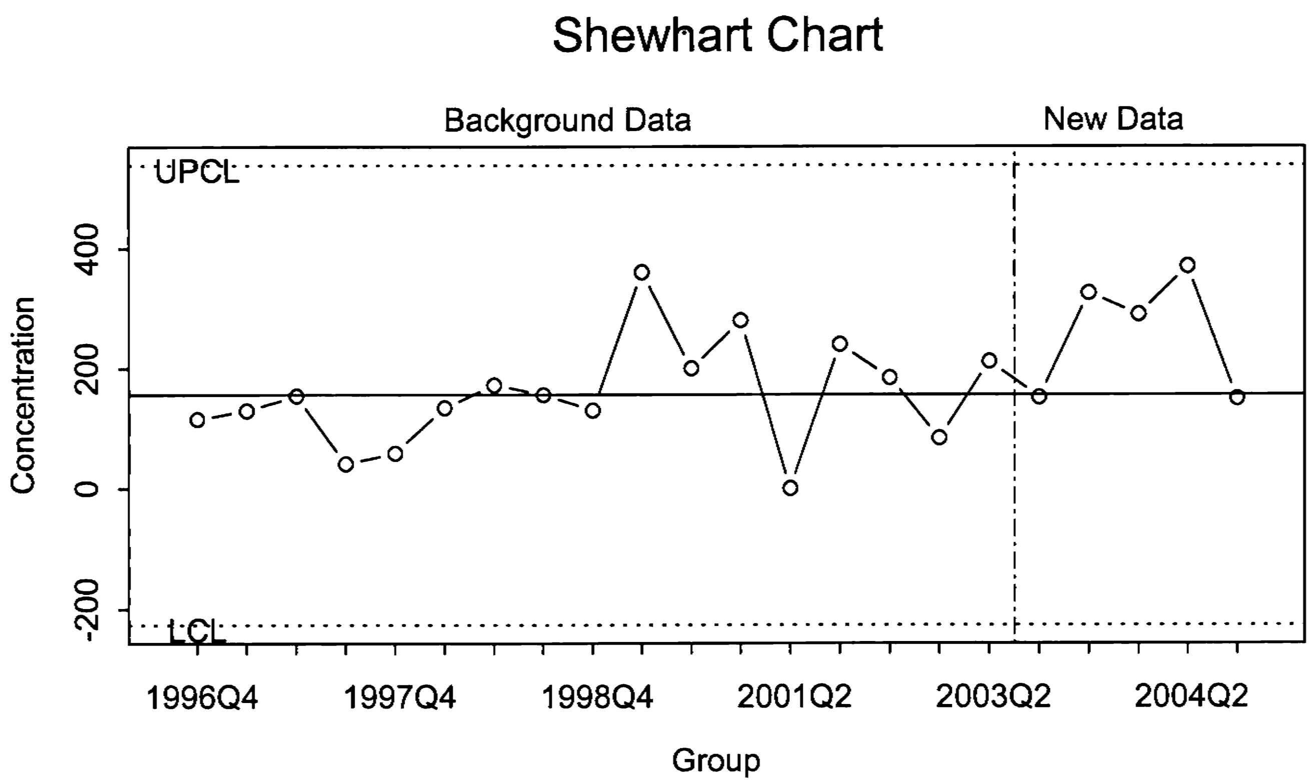


Shewhart Chart



GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-84D Chloride mg/l	



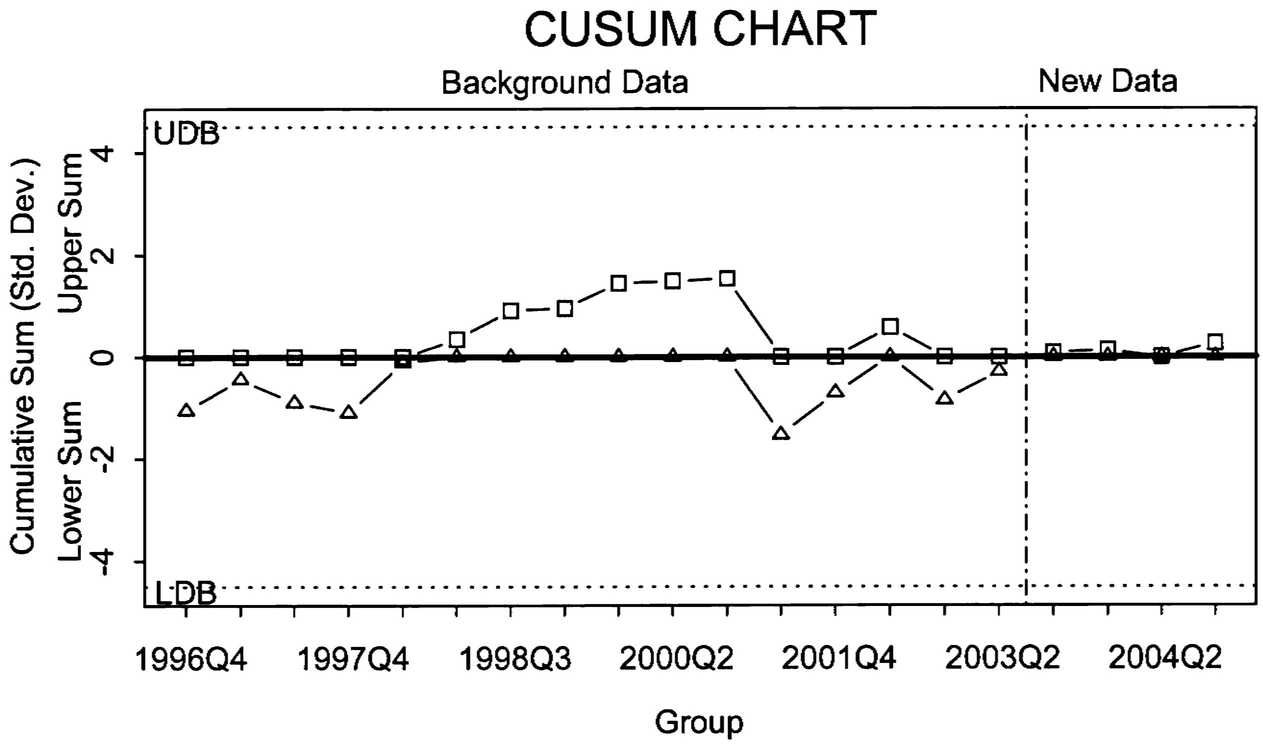


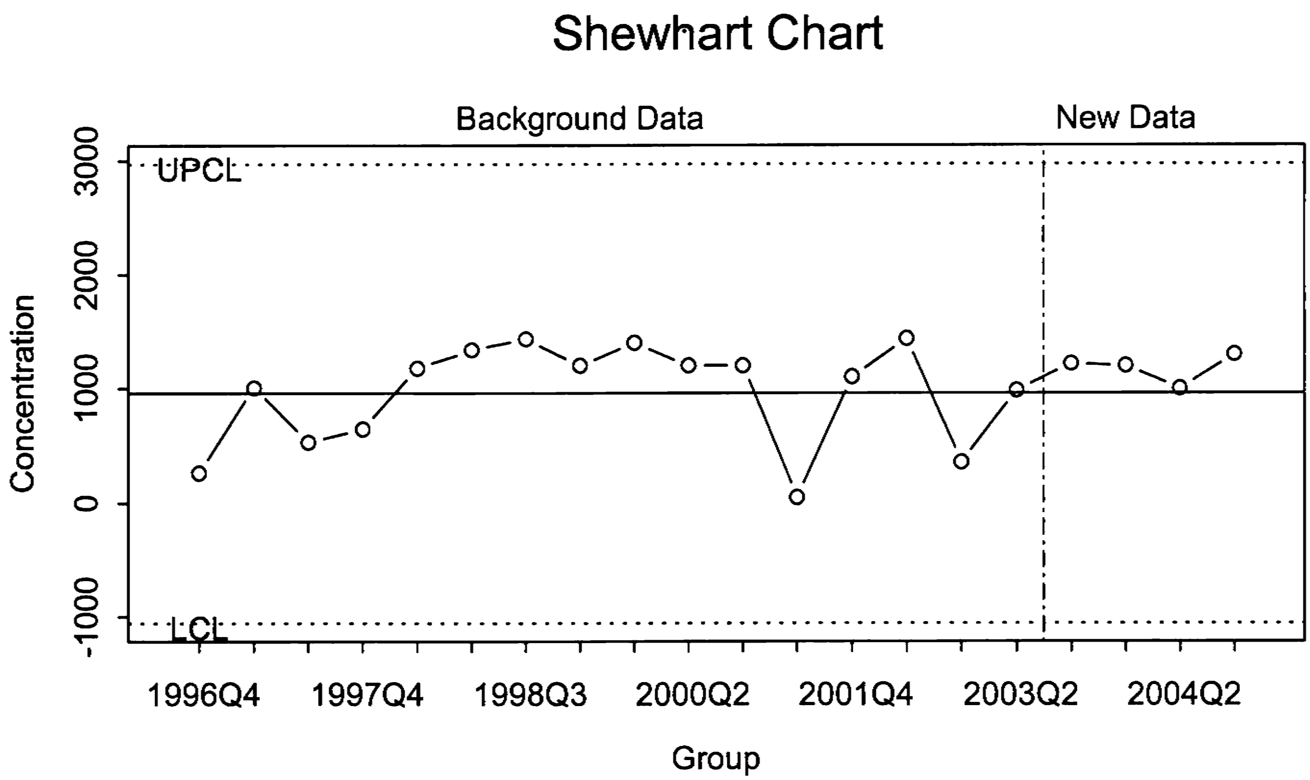
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-84D
Nitrogen, Ammonia
mg/l





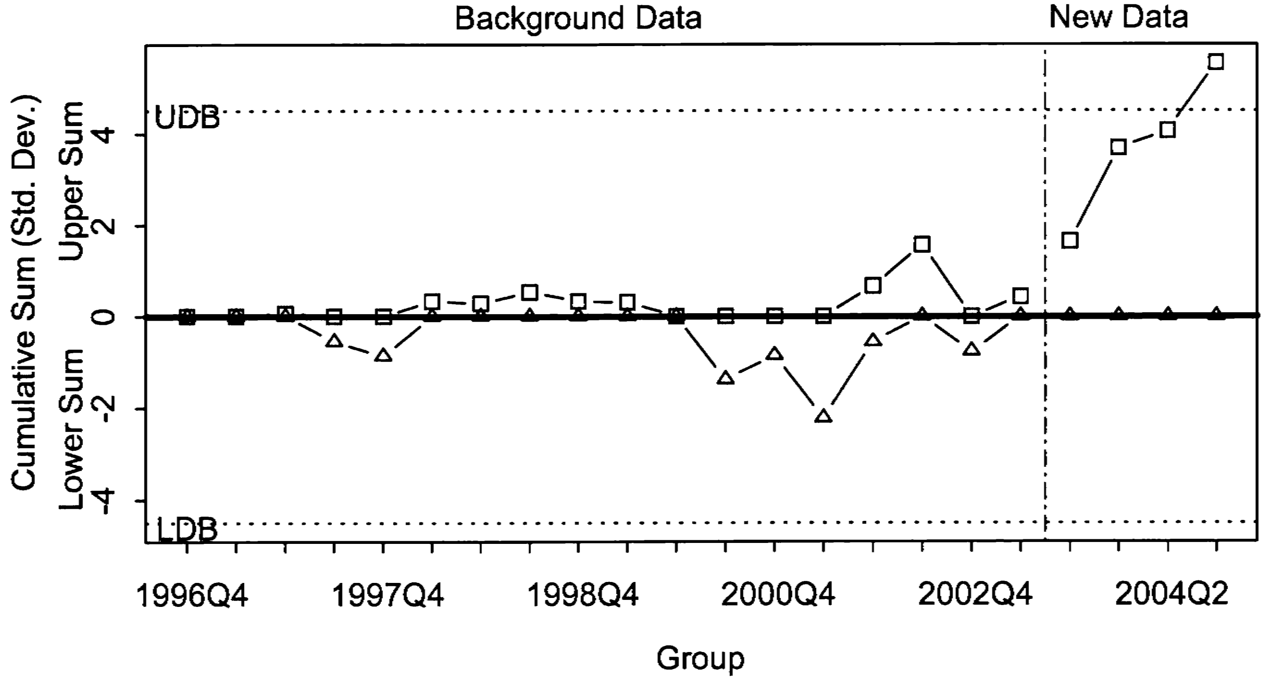
GEOMEGA

5/18/05

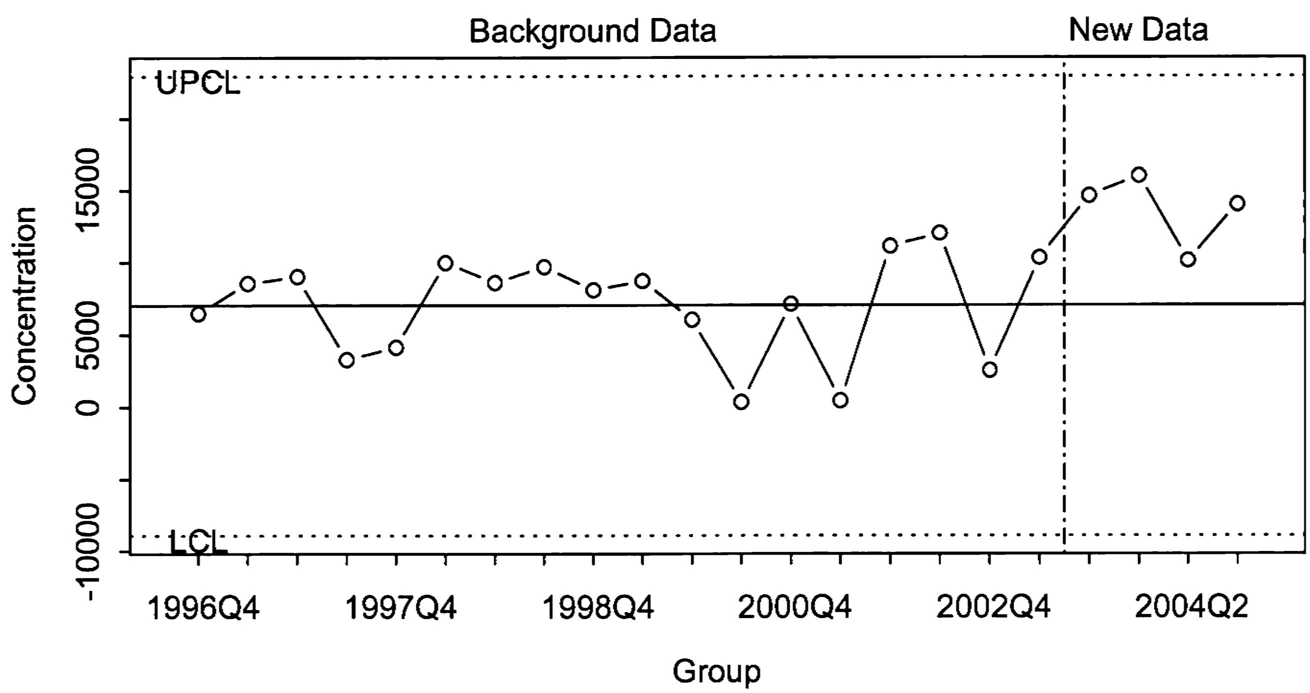
C03302C
Olin-Wilmington

GW-84D
Sodium, Dissolved
mg/l

CUSUM CHART



Shewhart Chart

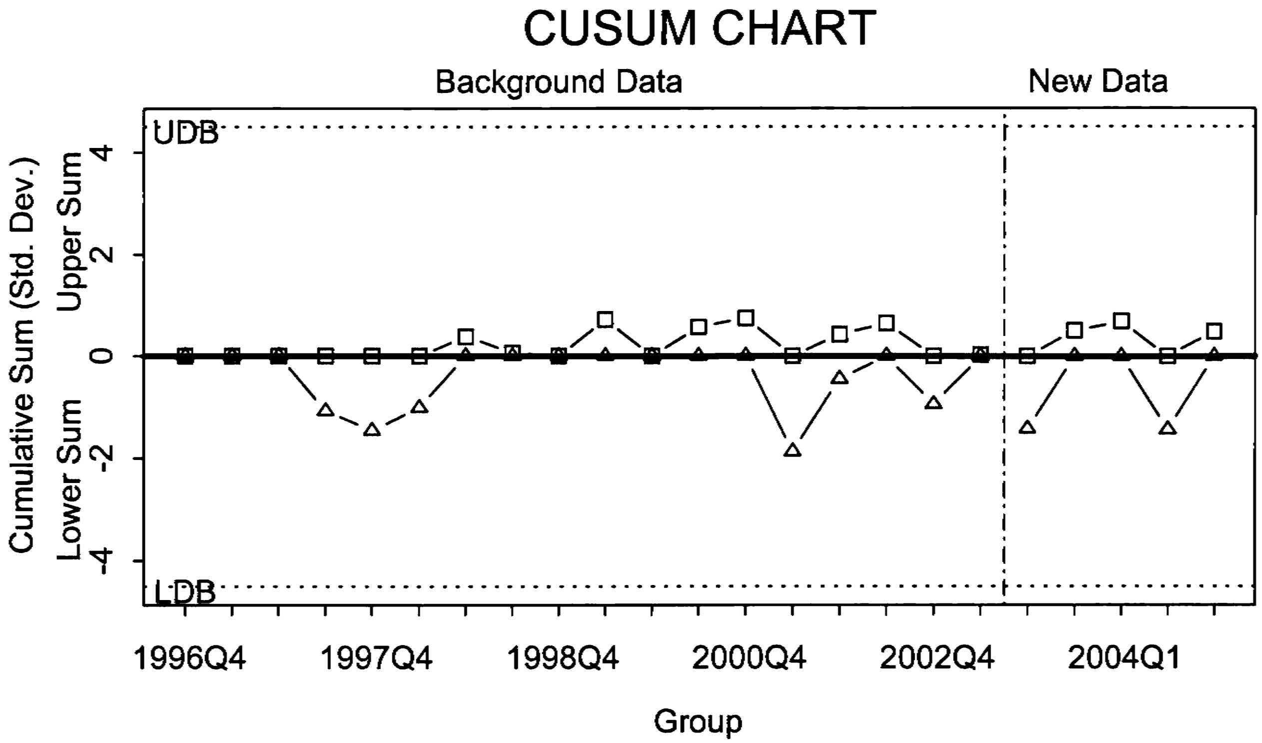


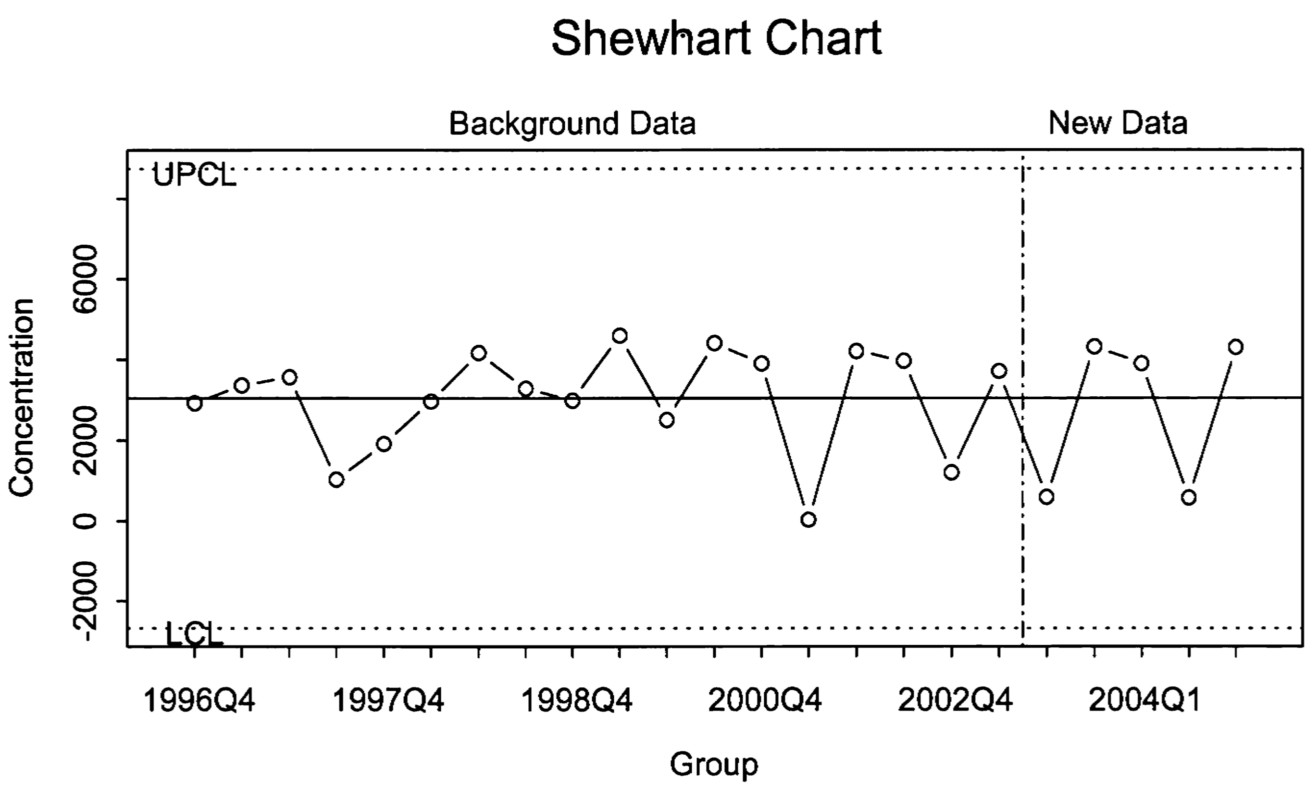
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-84D
Specific Conductance
umhos/cm



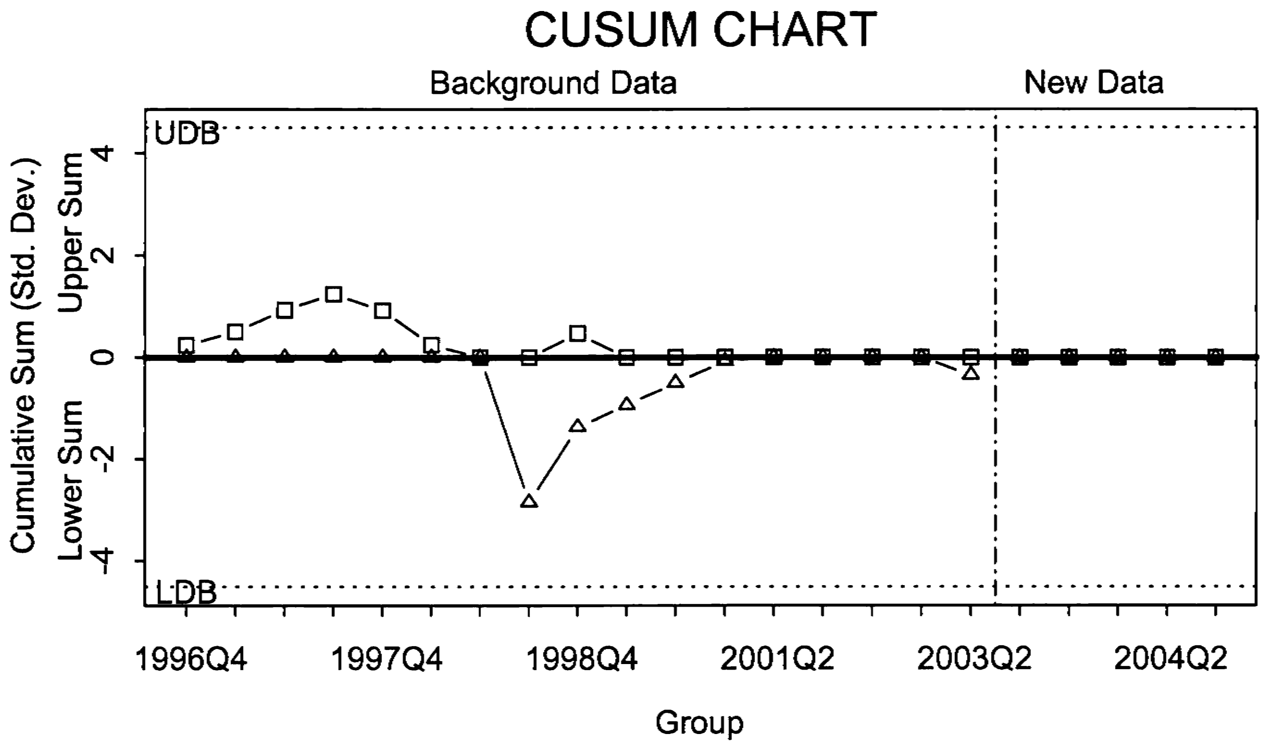


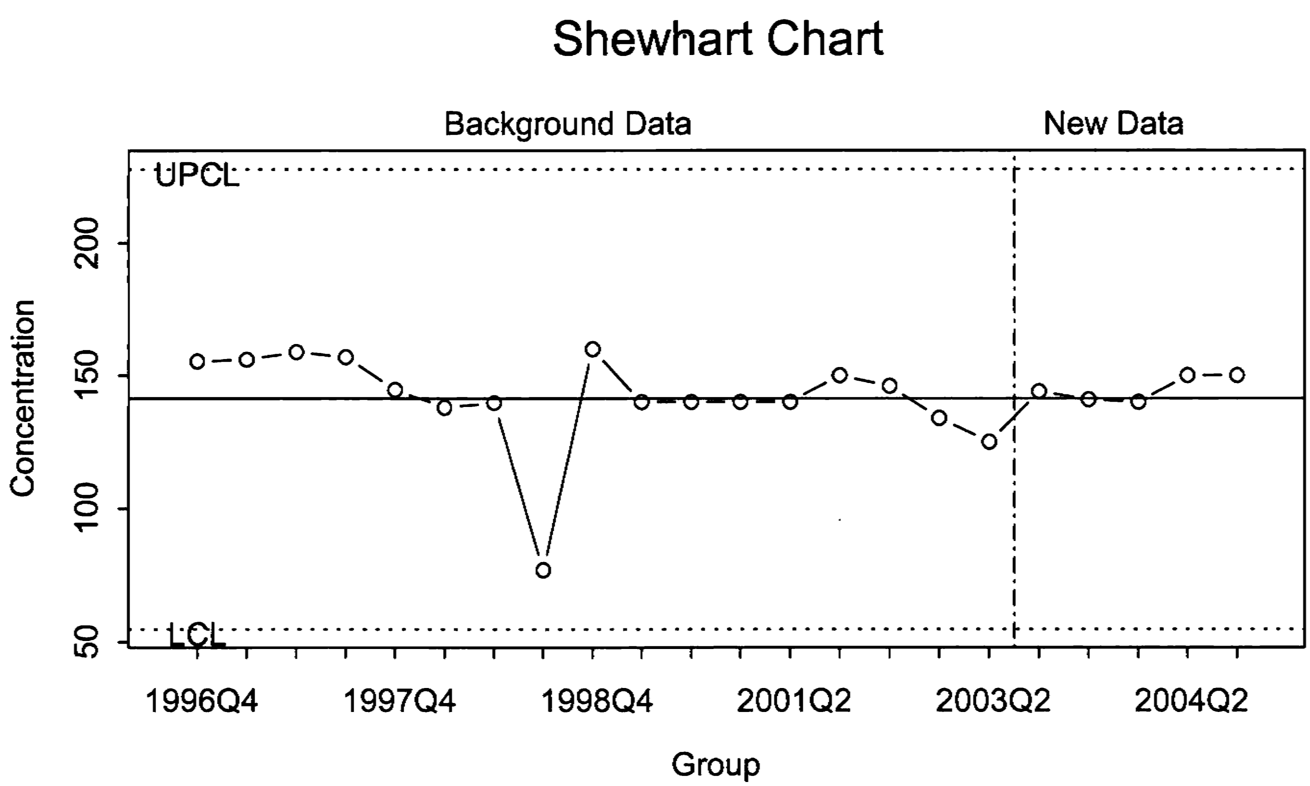
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-84D
Sulfate as SO4
mg/l



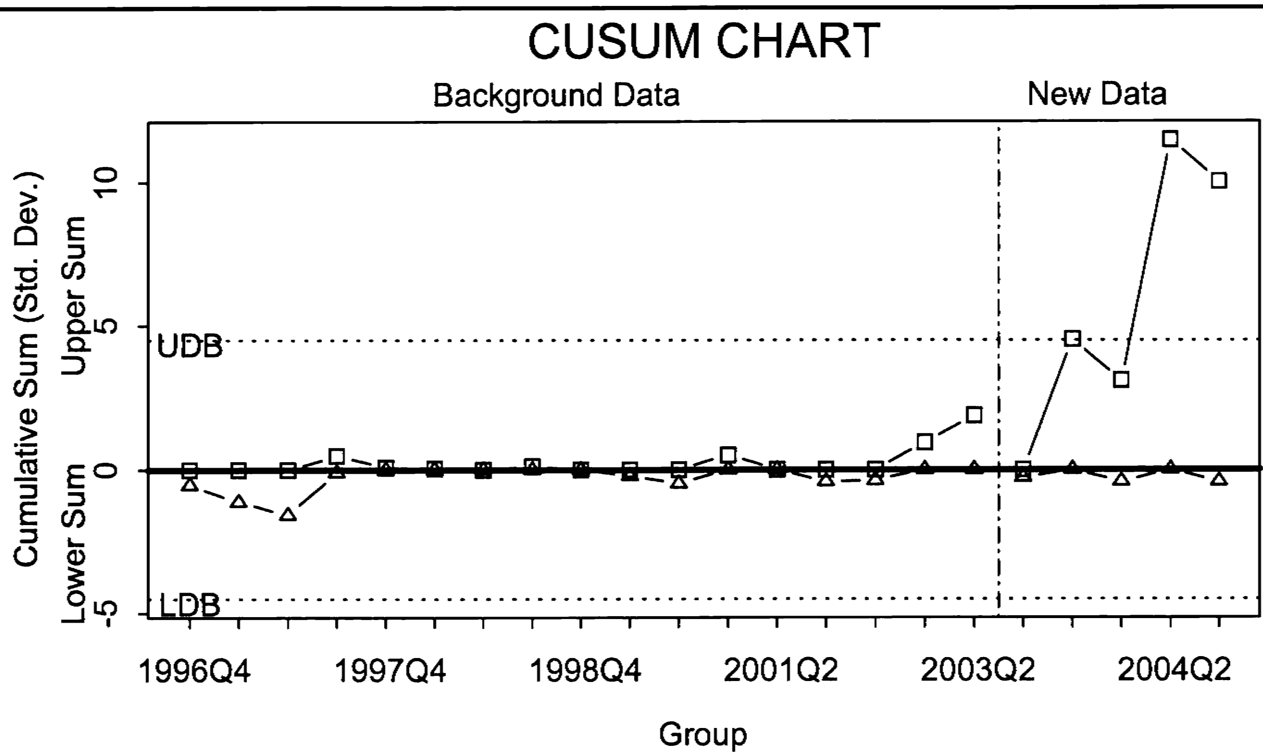


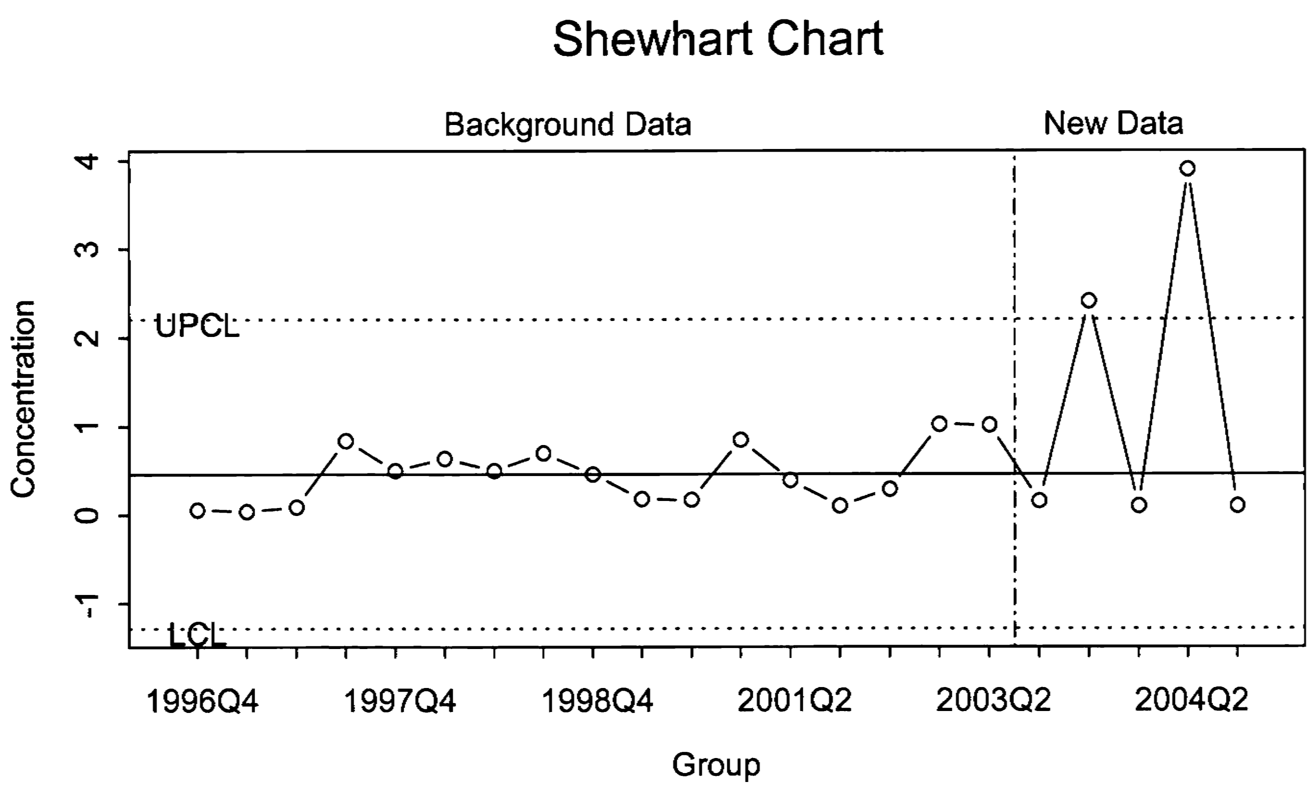
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-84M
Chloride
mg/l



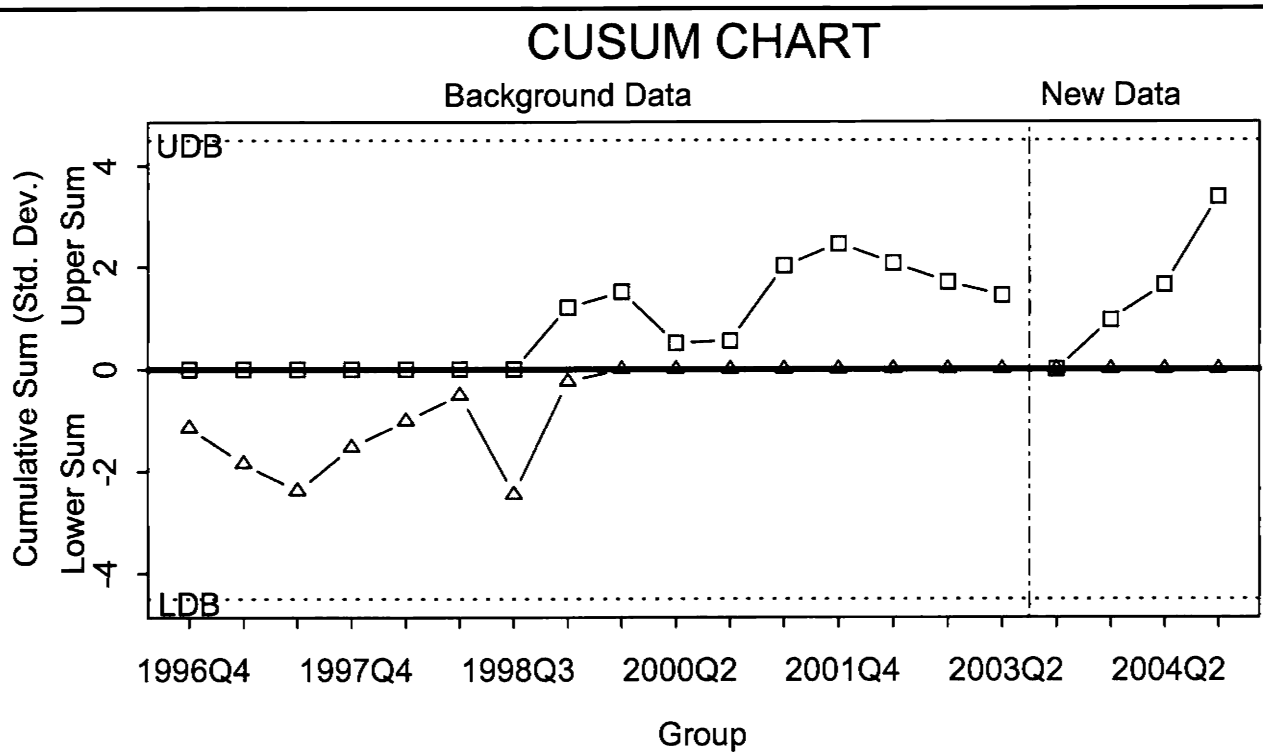


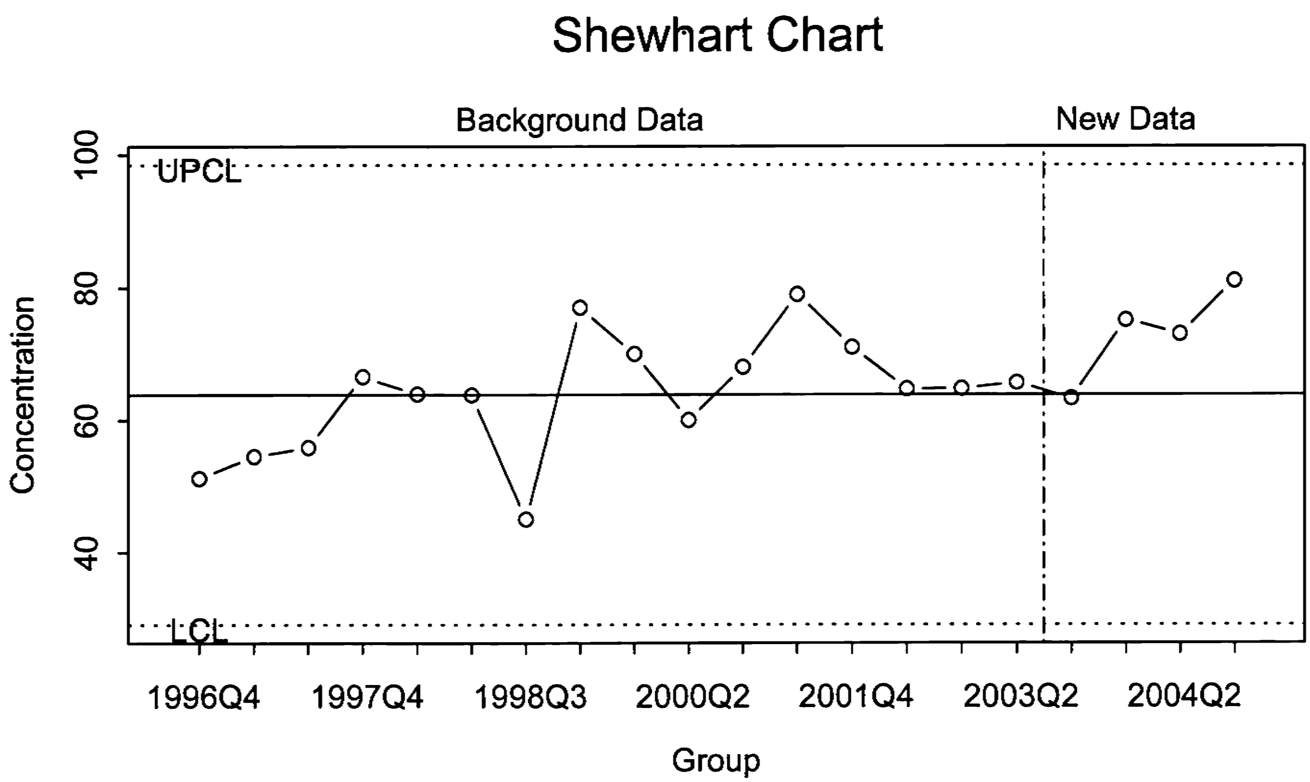
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-84M
Nitrogen, Ammonia
mg/l





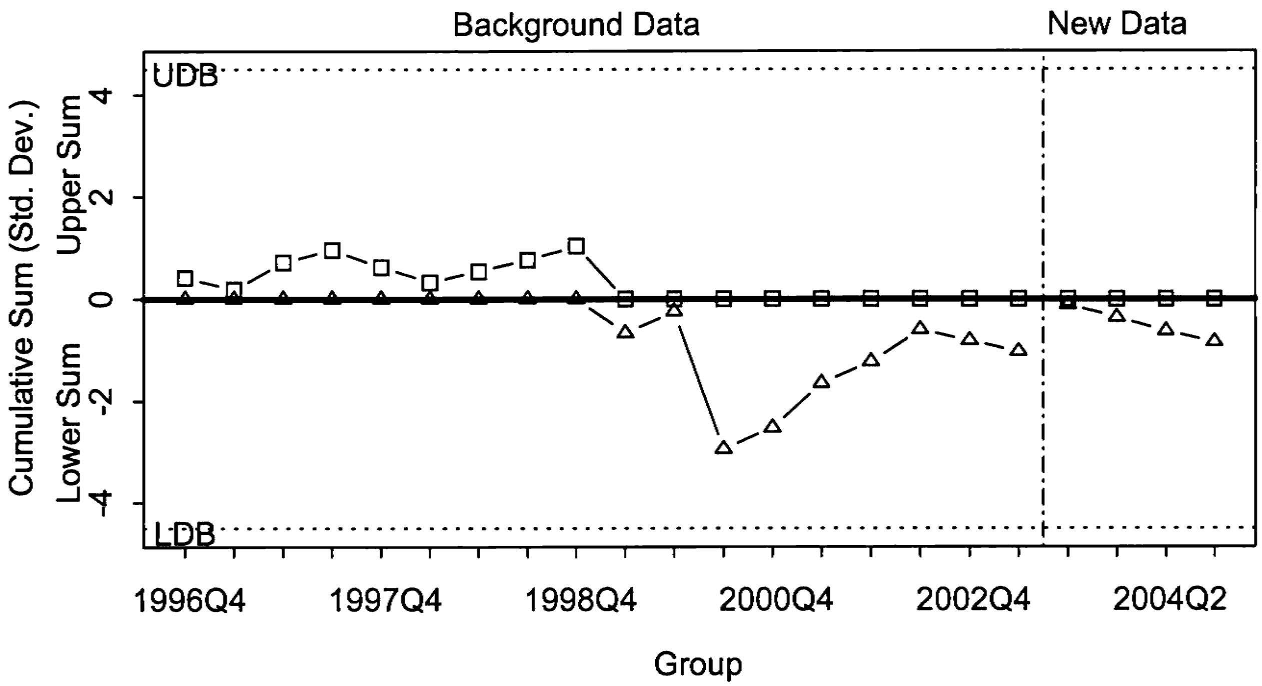
GEOMEGA

5/18/05

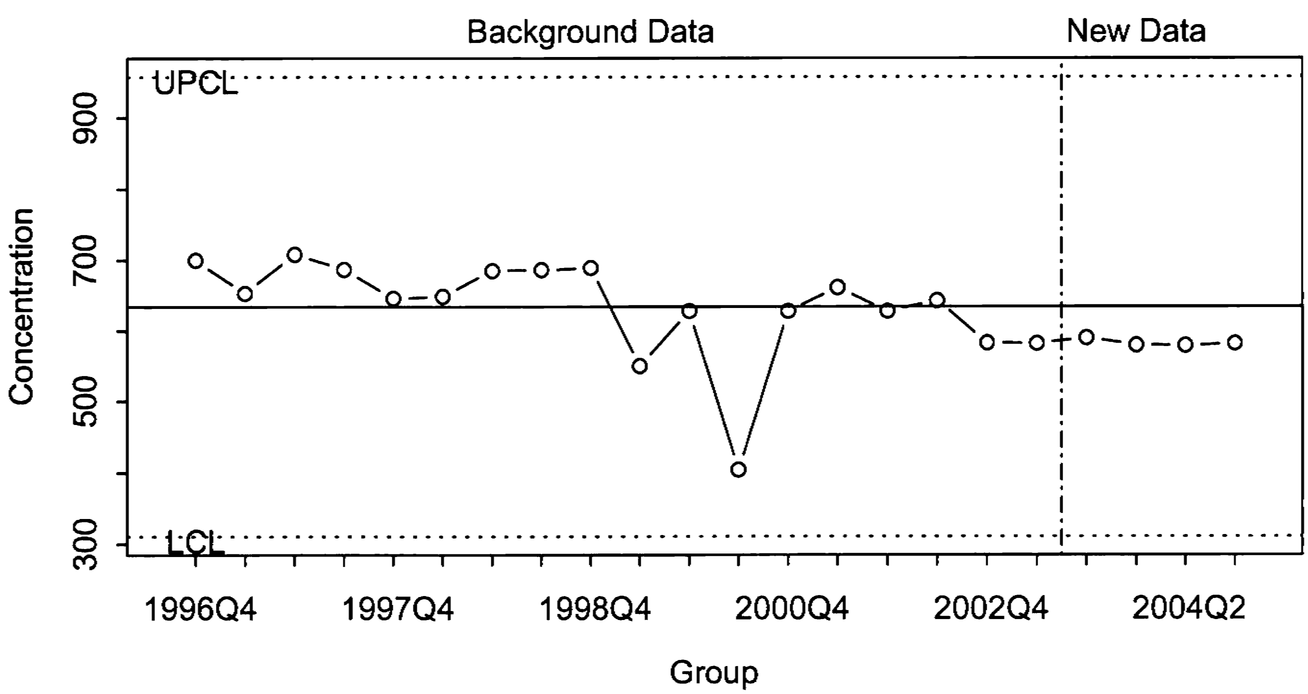
C03302C
Olin-Wilmington

GW-84M
Sodium, Dissolved
mg/l

CUSUM CHART



Shewhart Chart

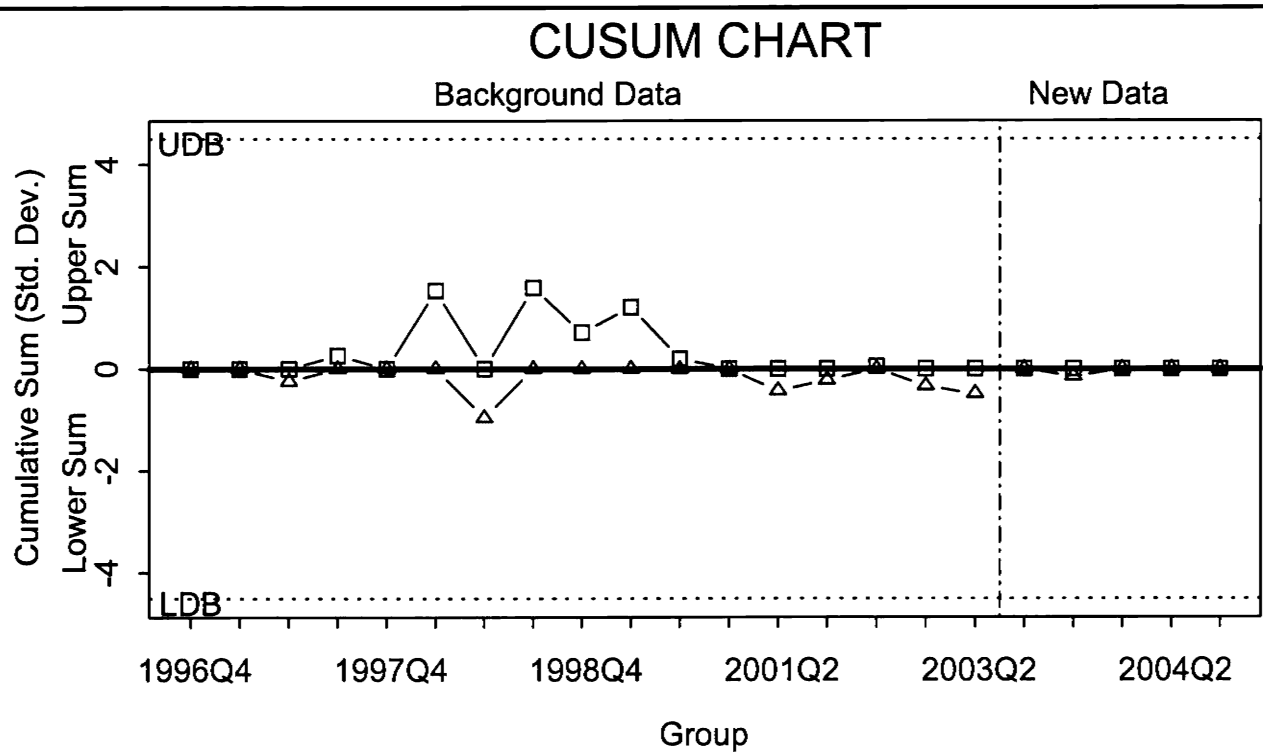


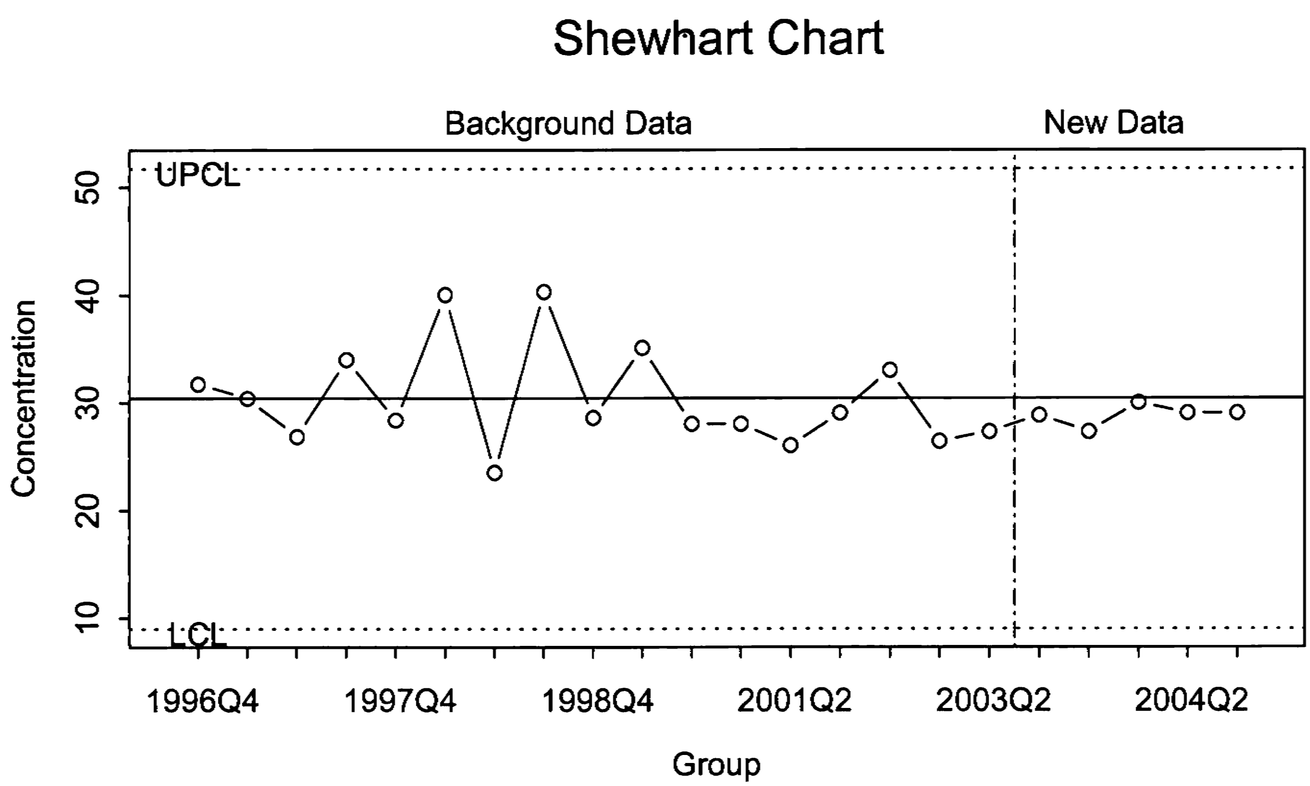
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-84M
Specific Conductance
umhos/cm



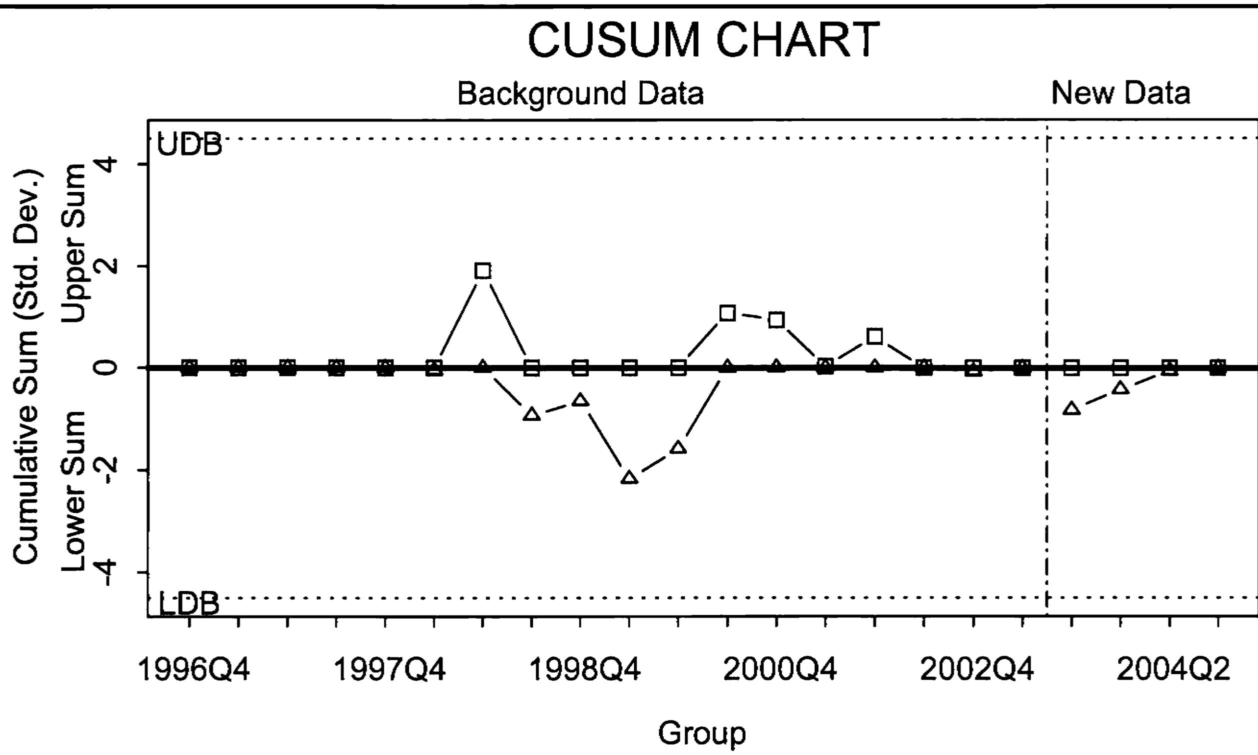


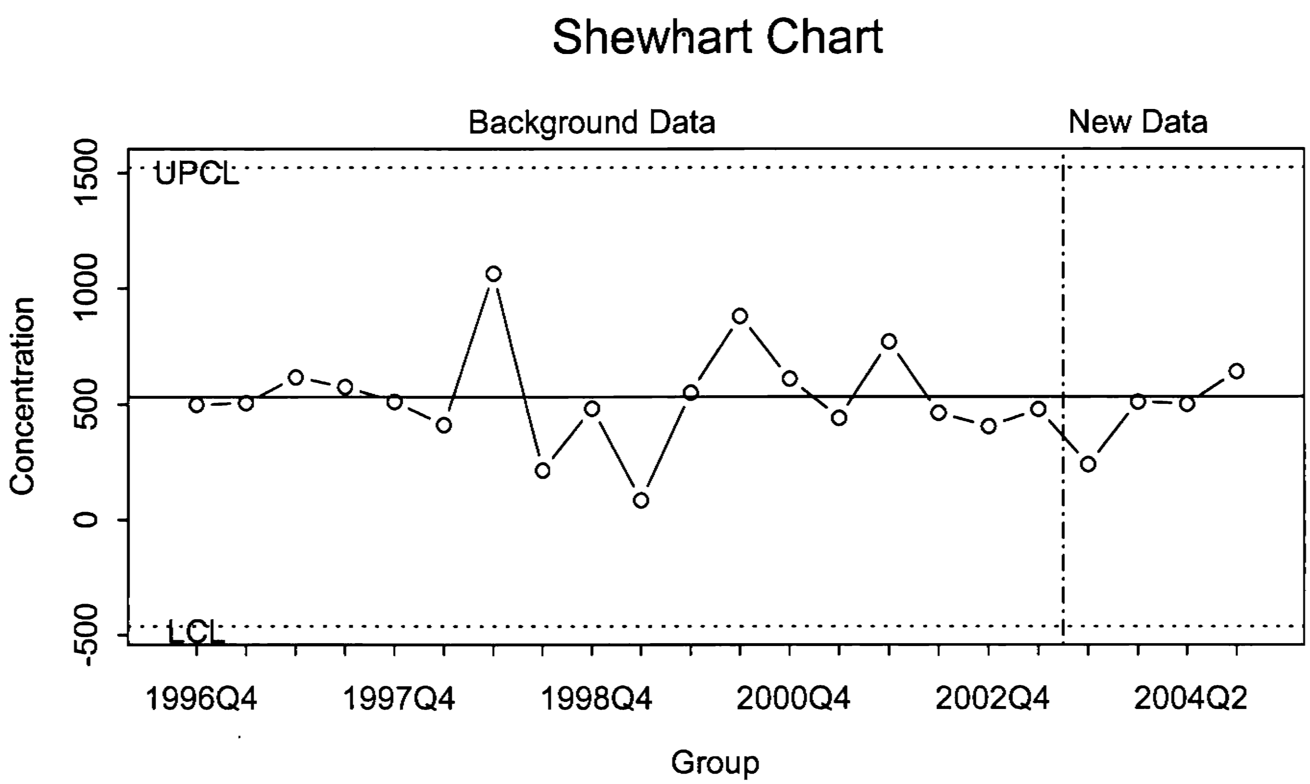
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-84M
Sulfate as SO4
mg/l



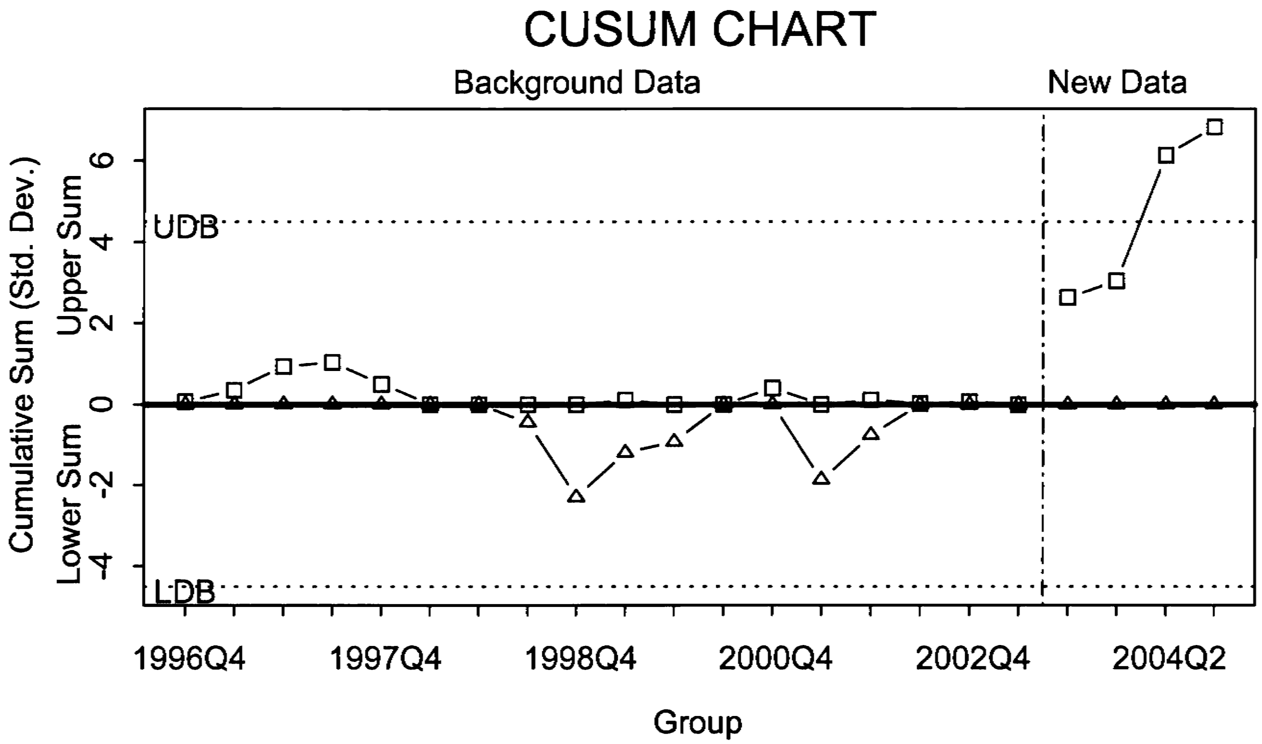


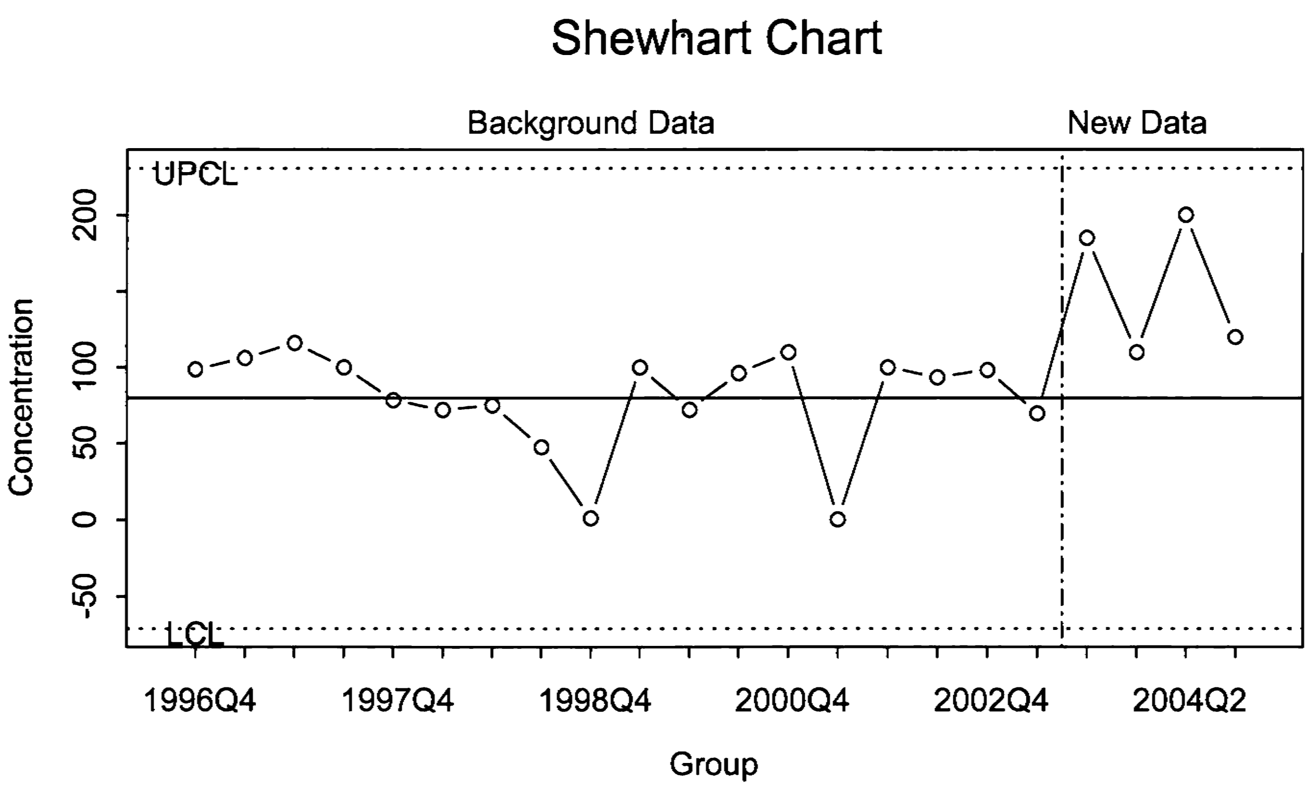
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-85D
Chloride
mg/l



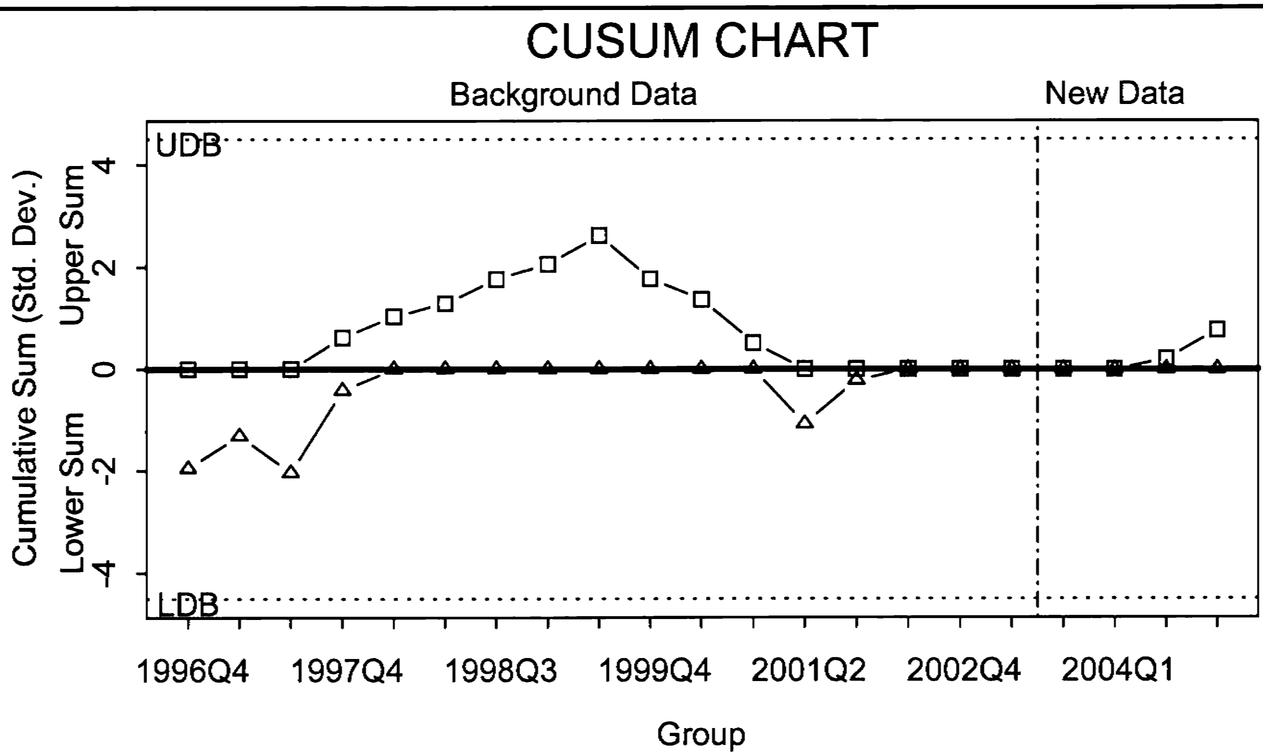


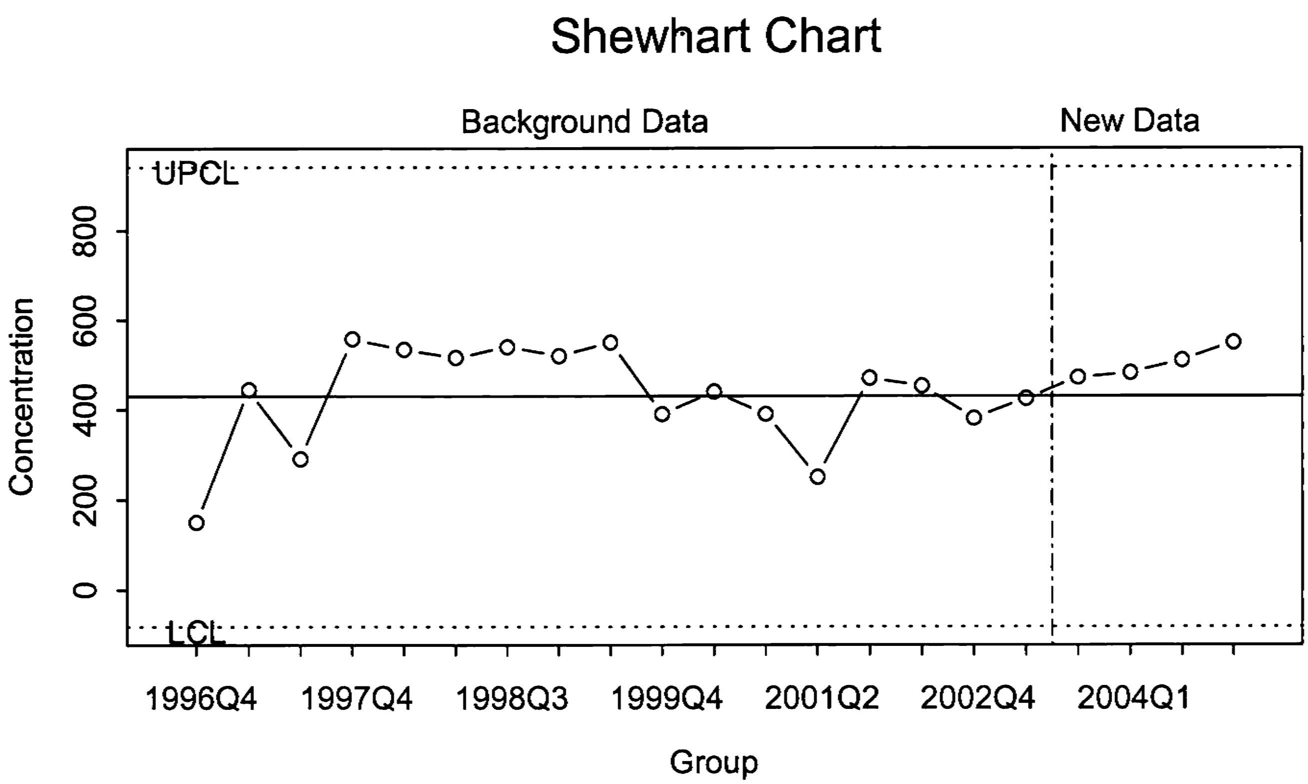
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-85D
Nitrogen, Ammonia
mg/l



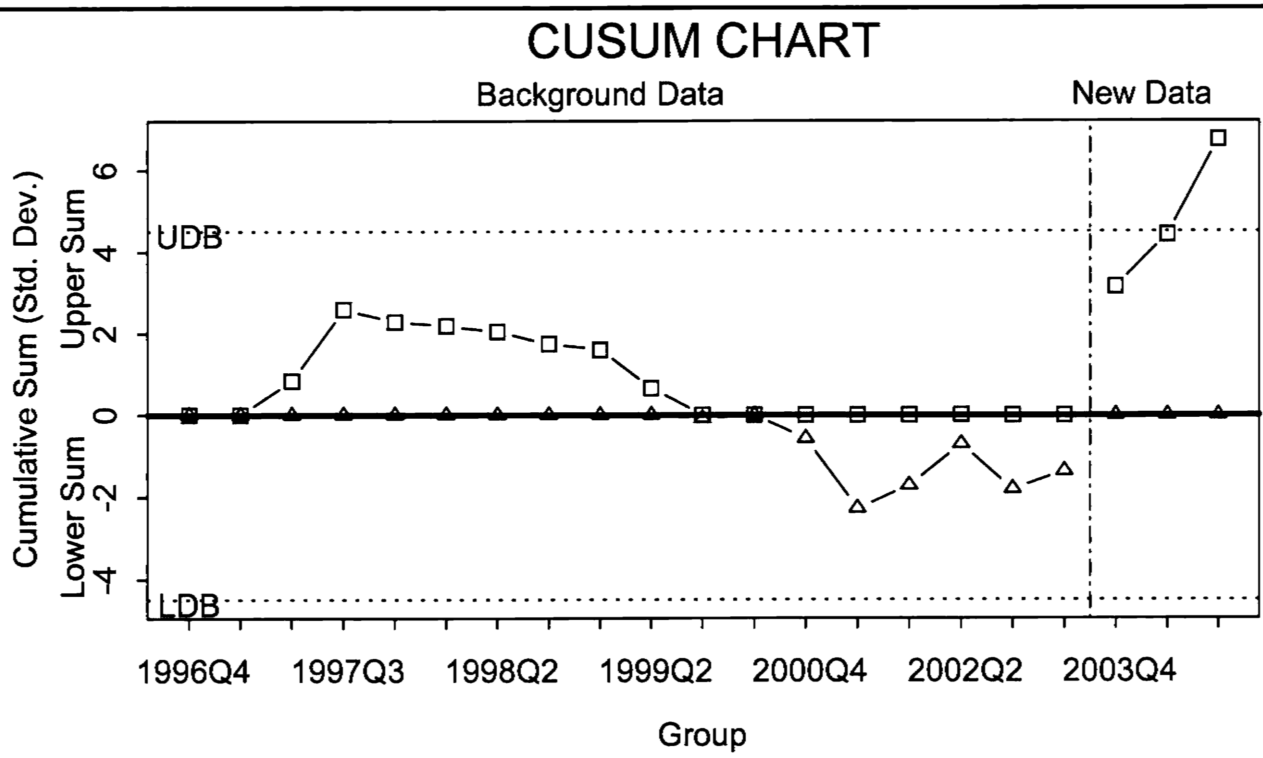


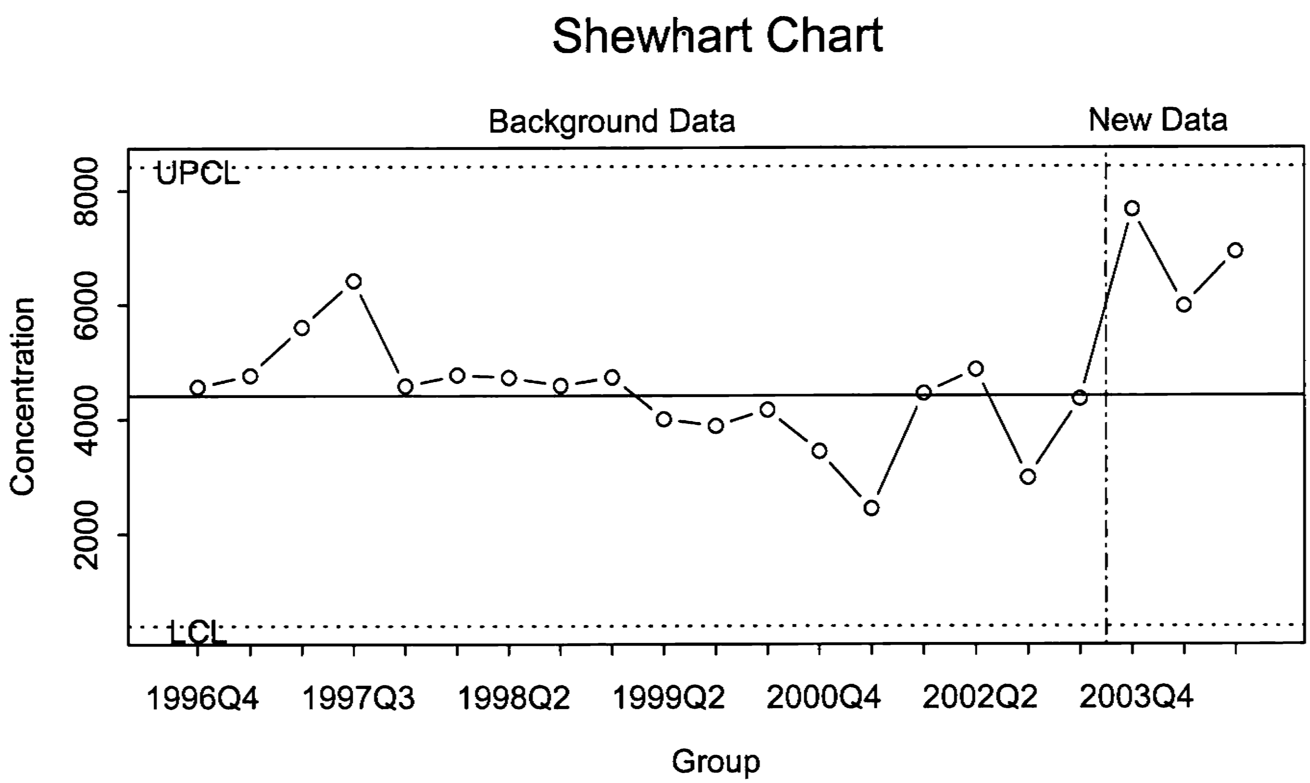
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-85D
Sodium, Dissolved
mg/l





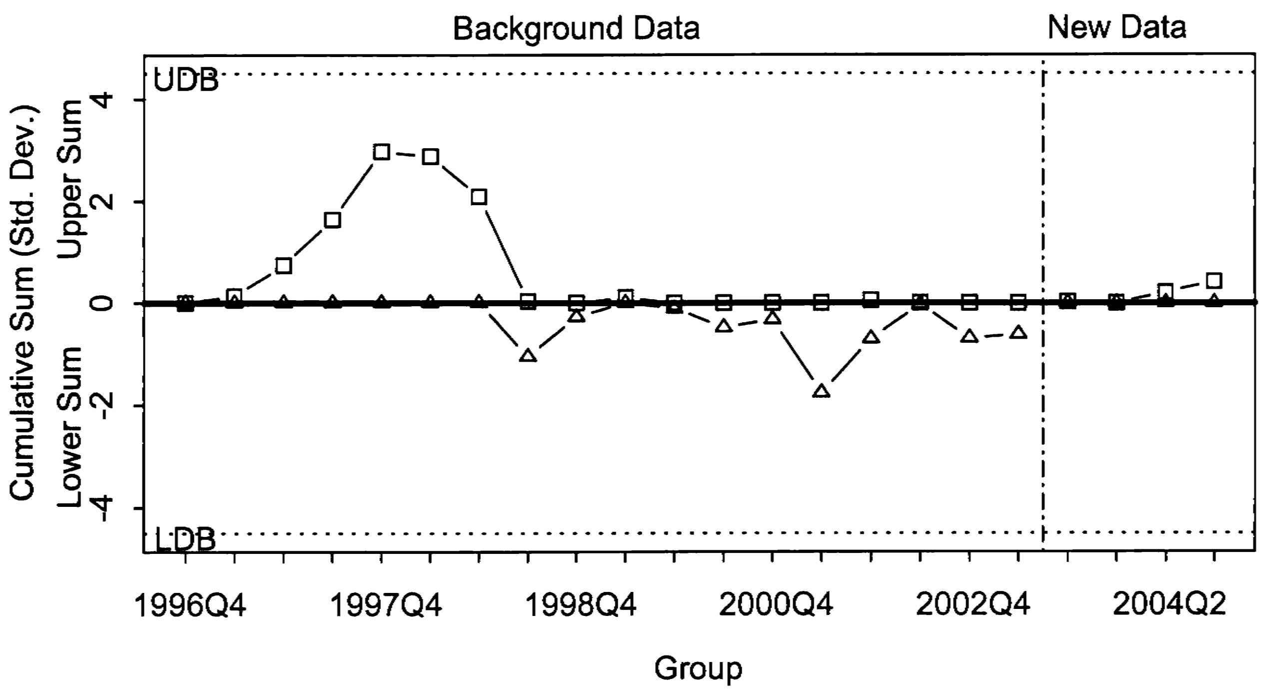
GEOMEGA

5/18/05

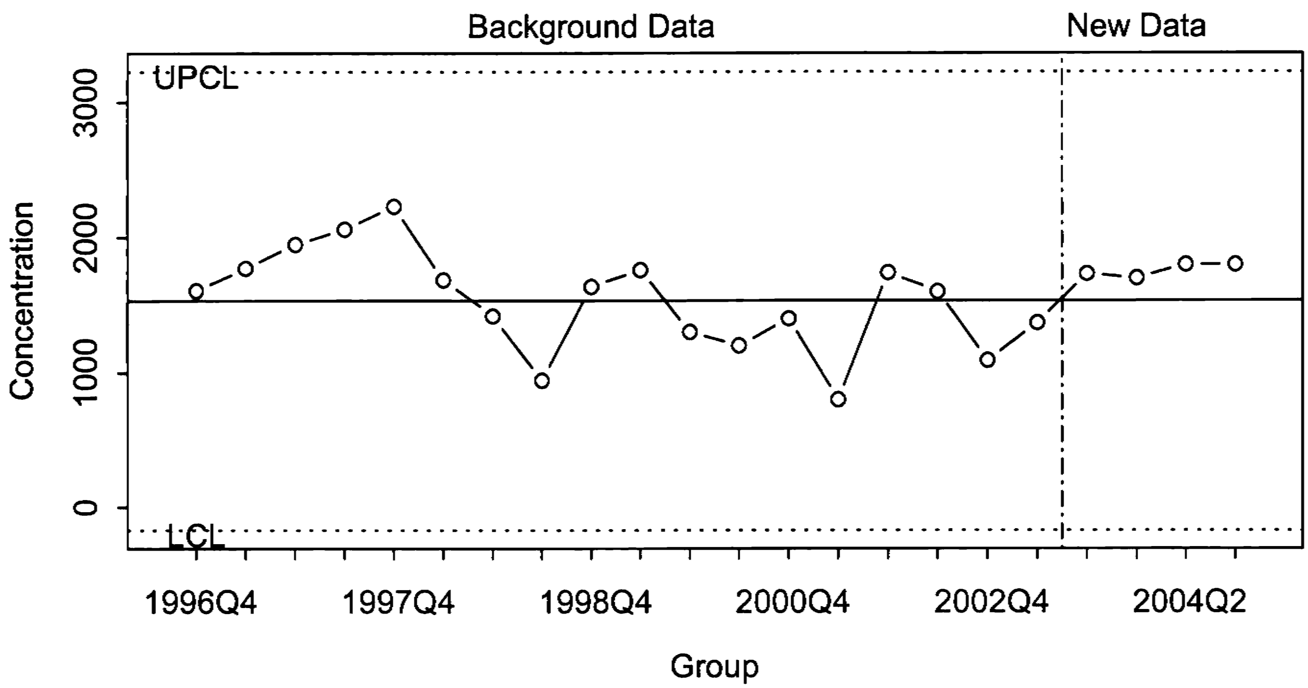
C03302C
Olin-Wilmington

GW-85D
Specific Conductance
umhos/cm

CUSUM CHART



Shewhart Chart

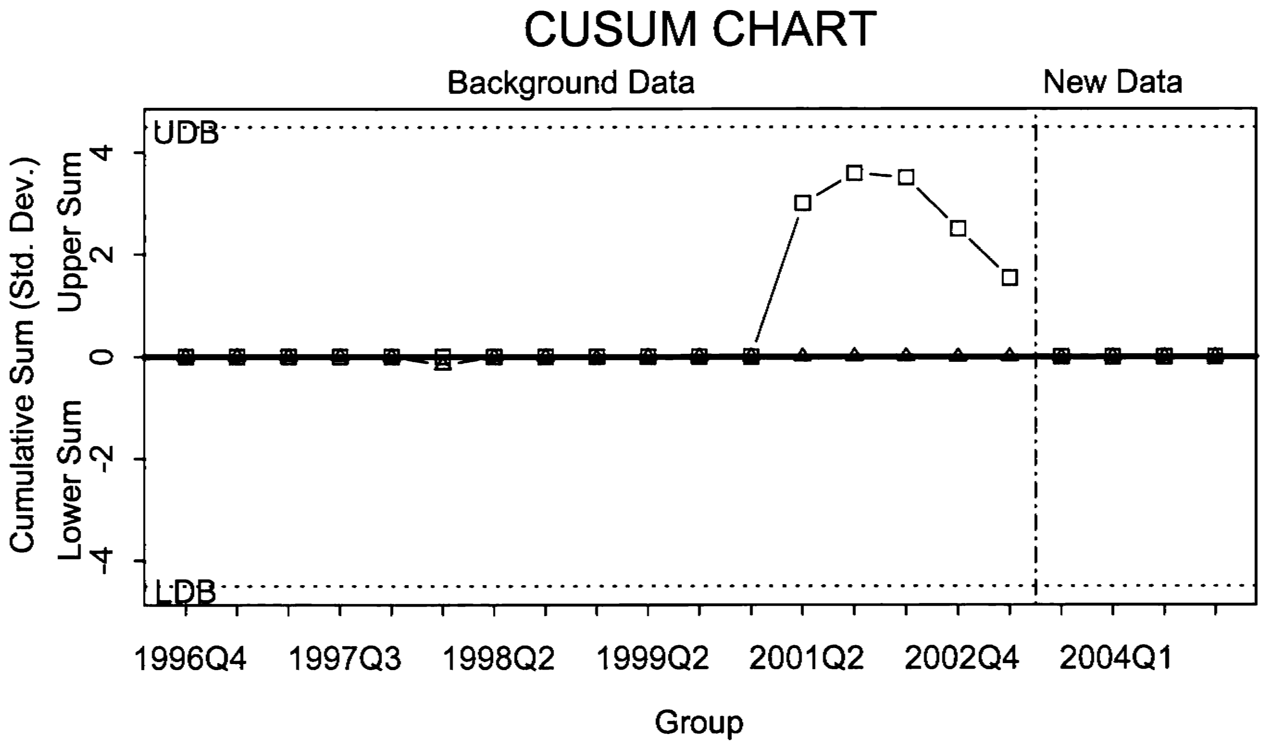


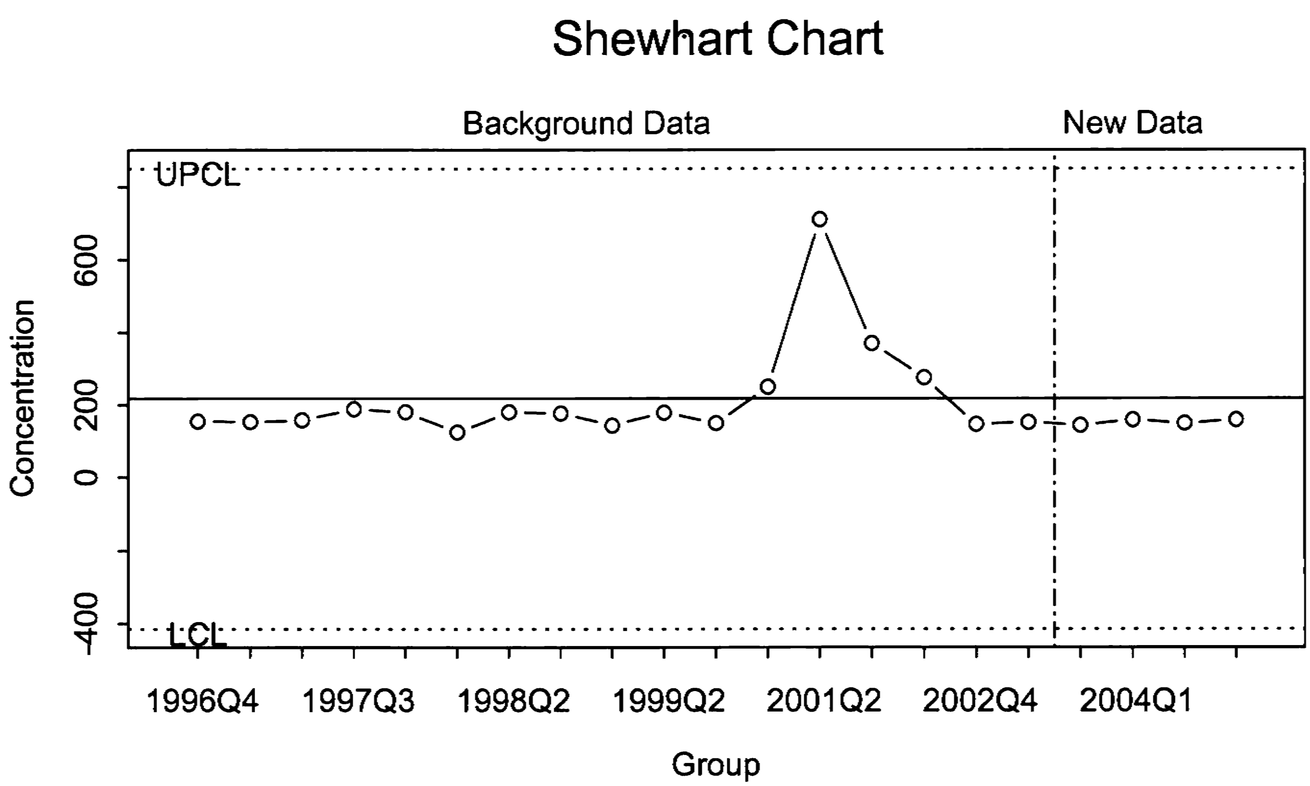
GEOMEGA

5/18/05

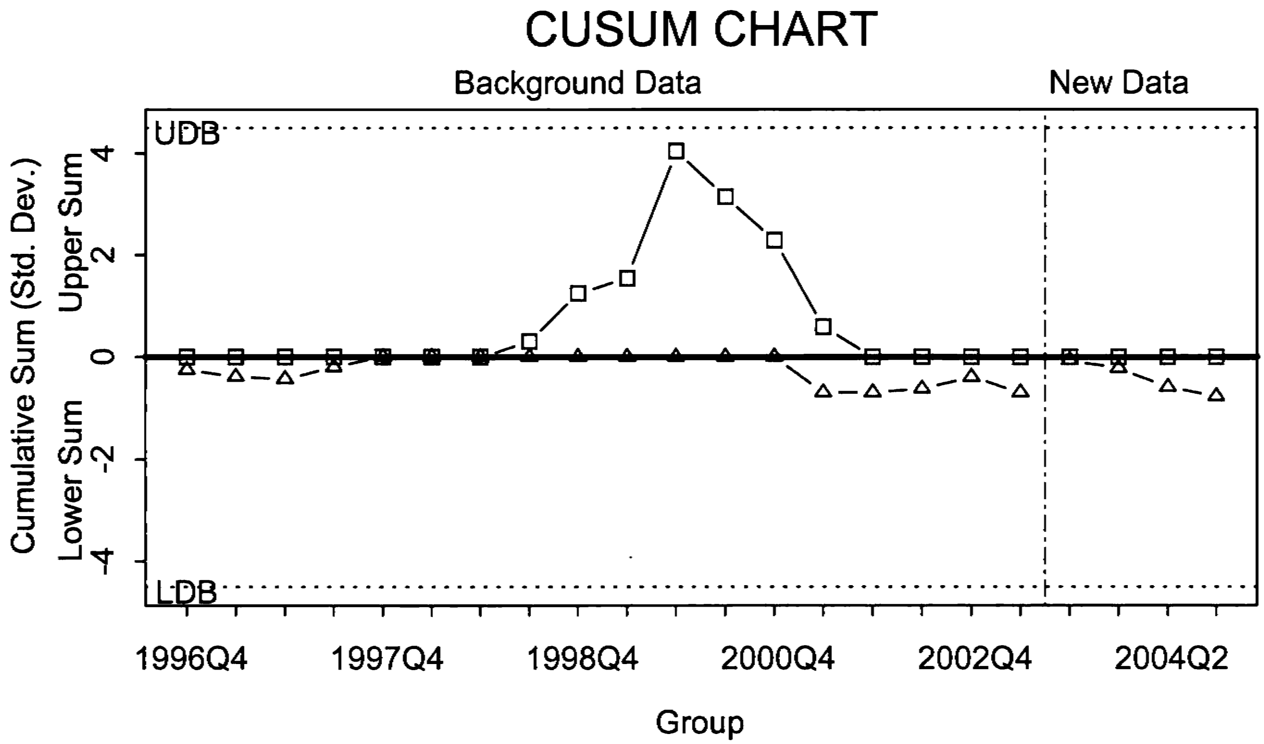
C03302C
Olin-Wilmington

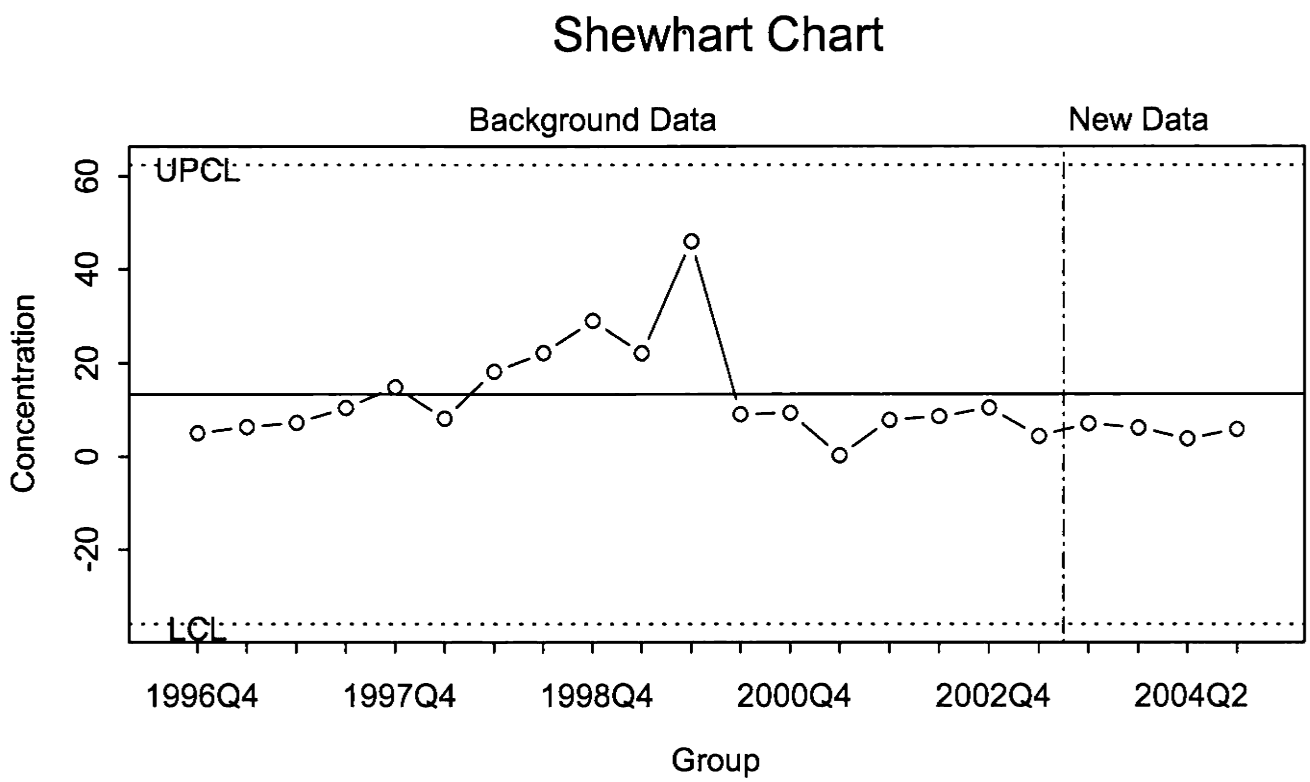
GW-85D
Sulfate as SO4
mg/l





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-85M Chloride mg/l	





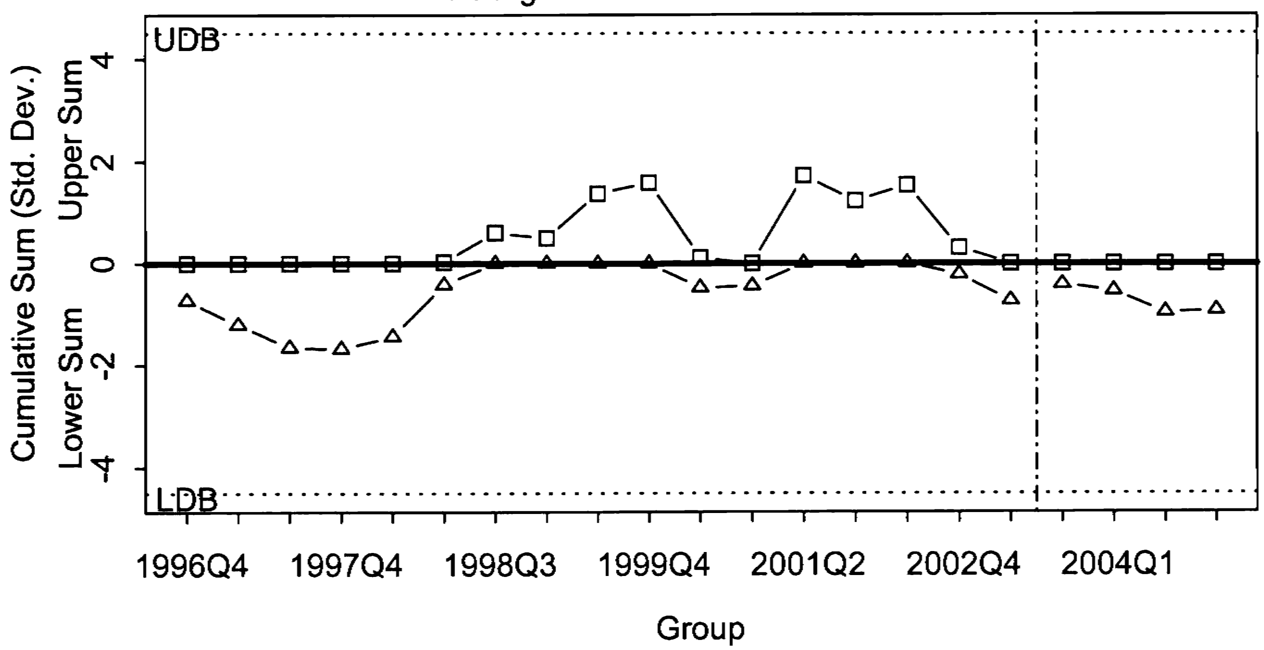
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-85M
Nitrogen, Ammonia
mg/l

CUSUM CHART



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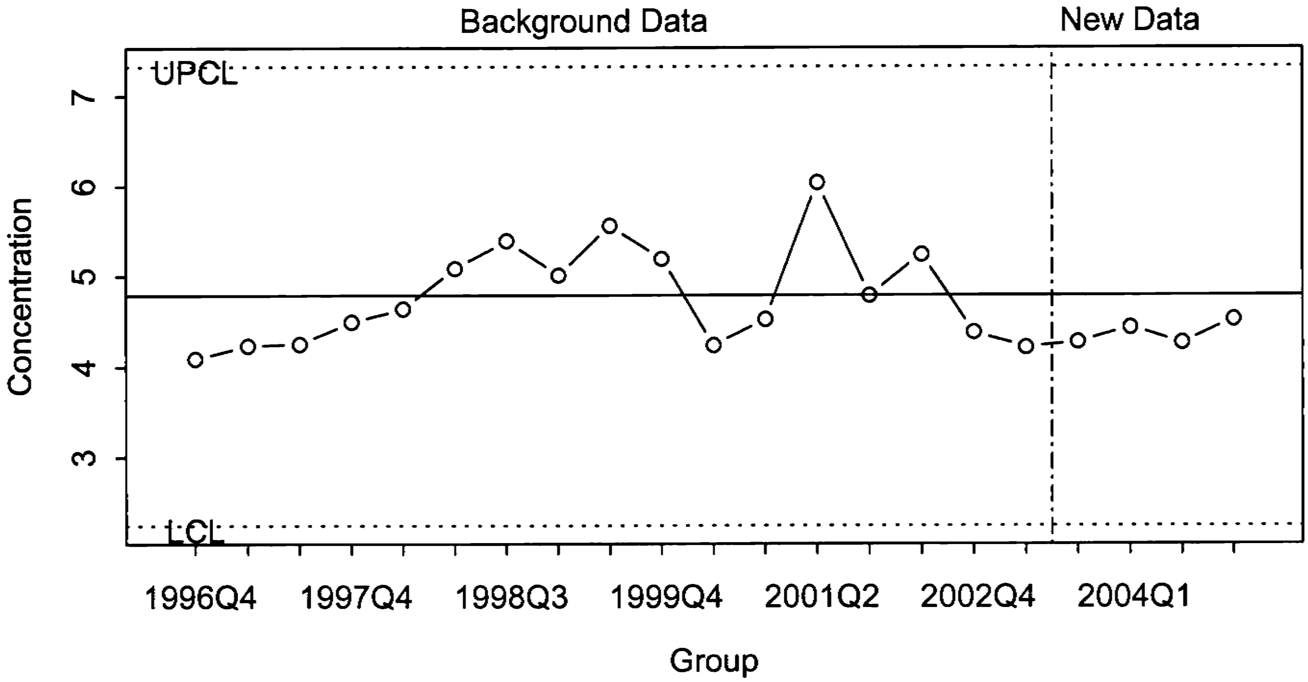


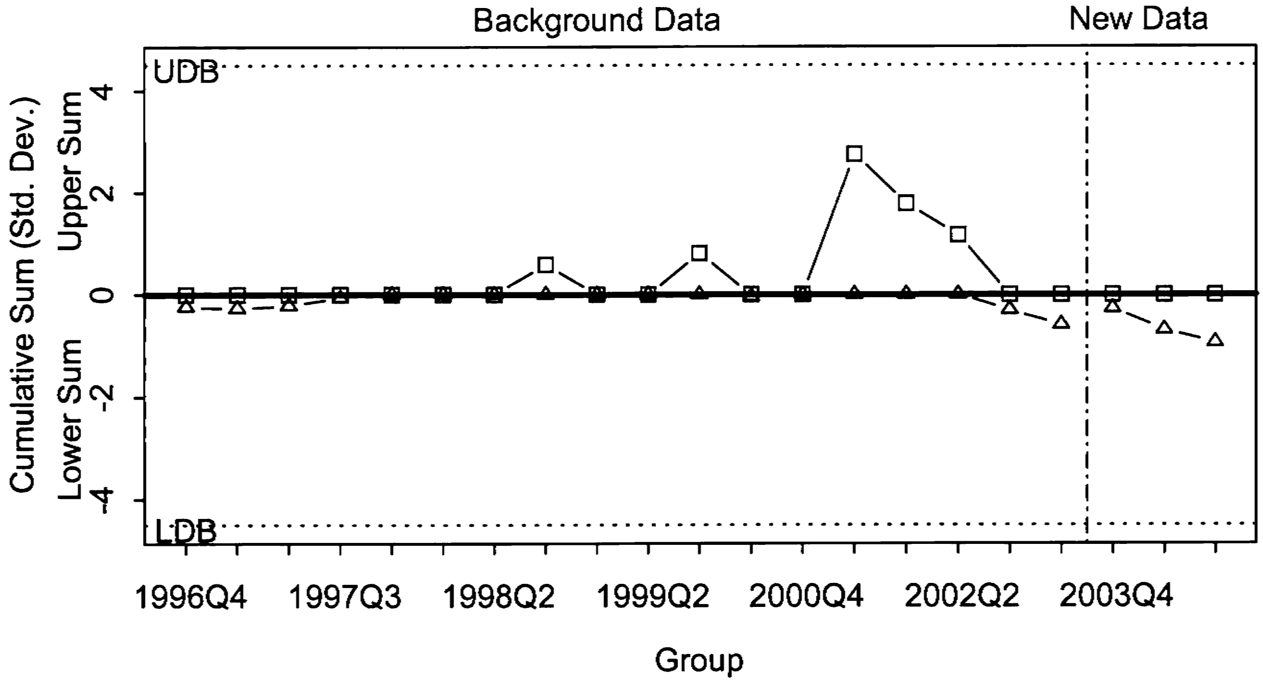
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-85M
Sodium, Dissolved
Log(mg/l)

CUSUM CHART



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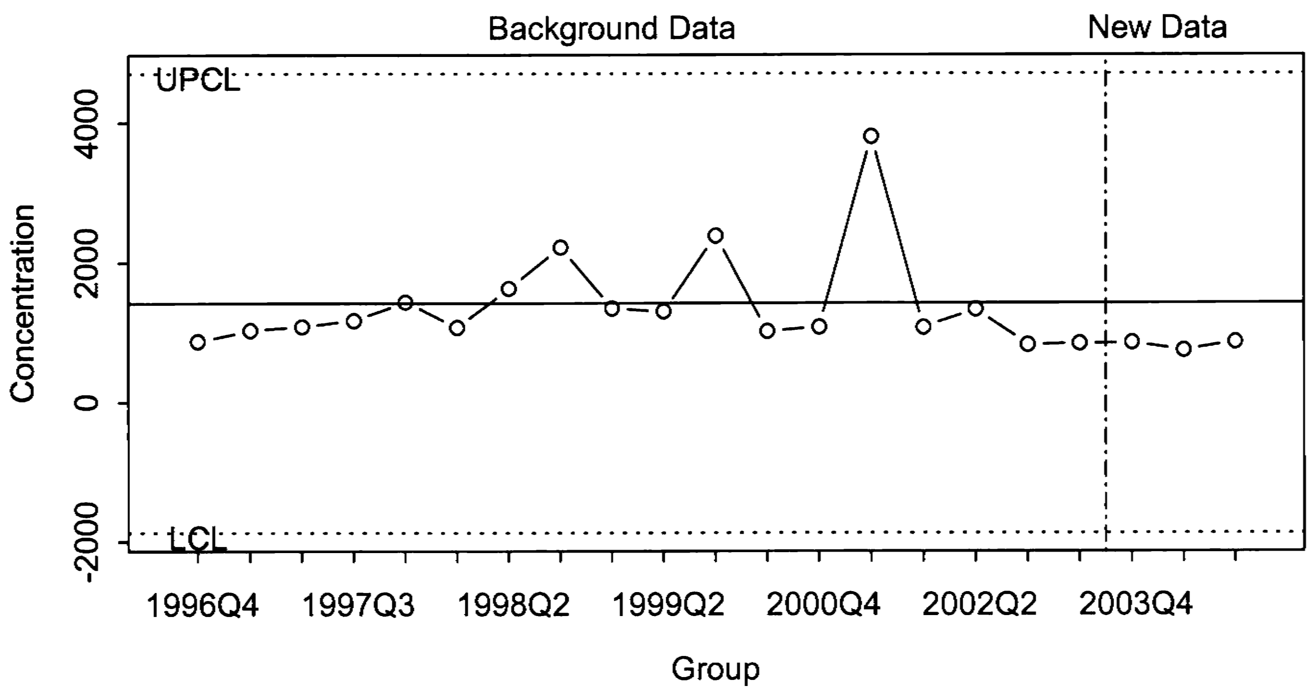
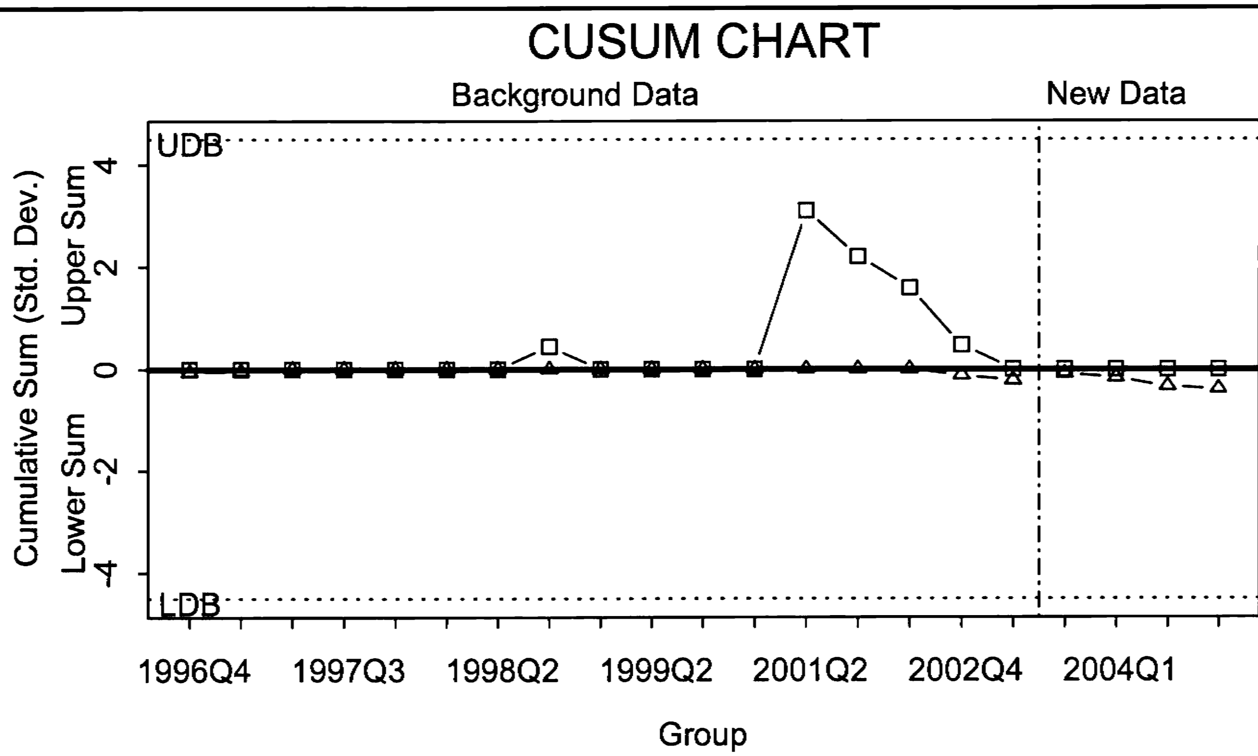


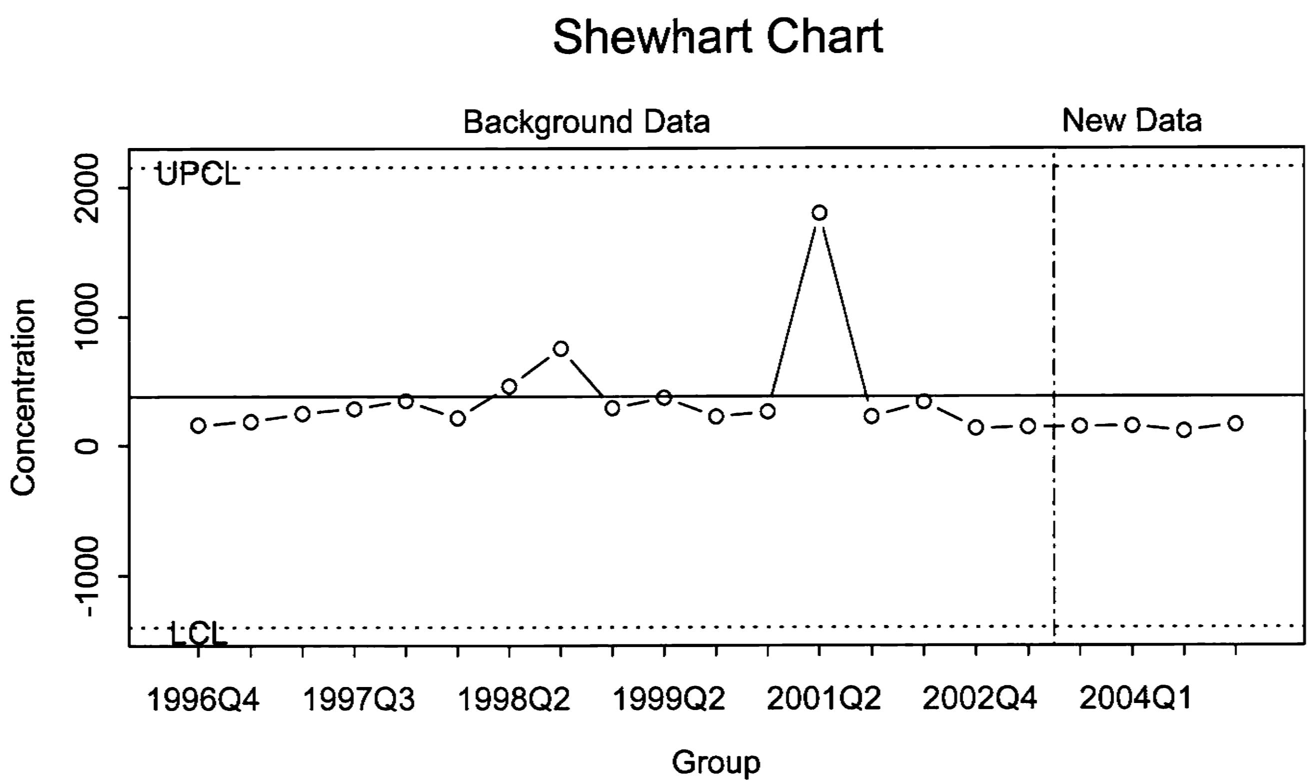
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-85M
Specific Conductance
umhos/cm



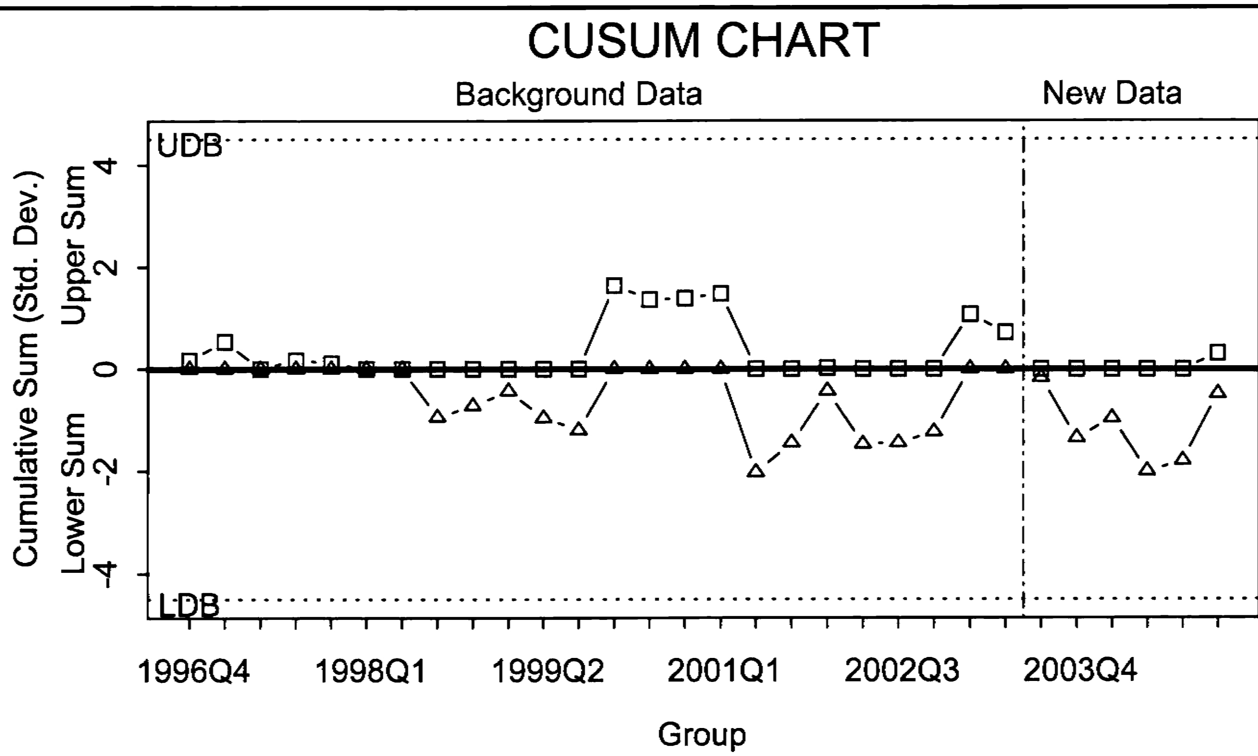


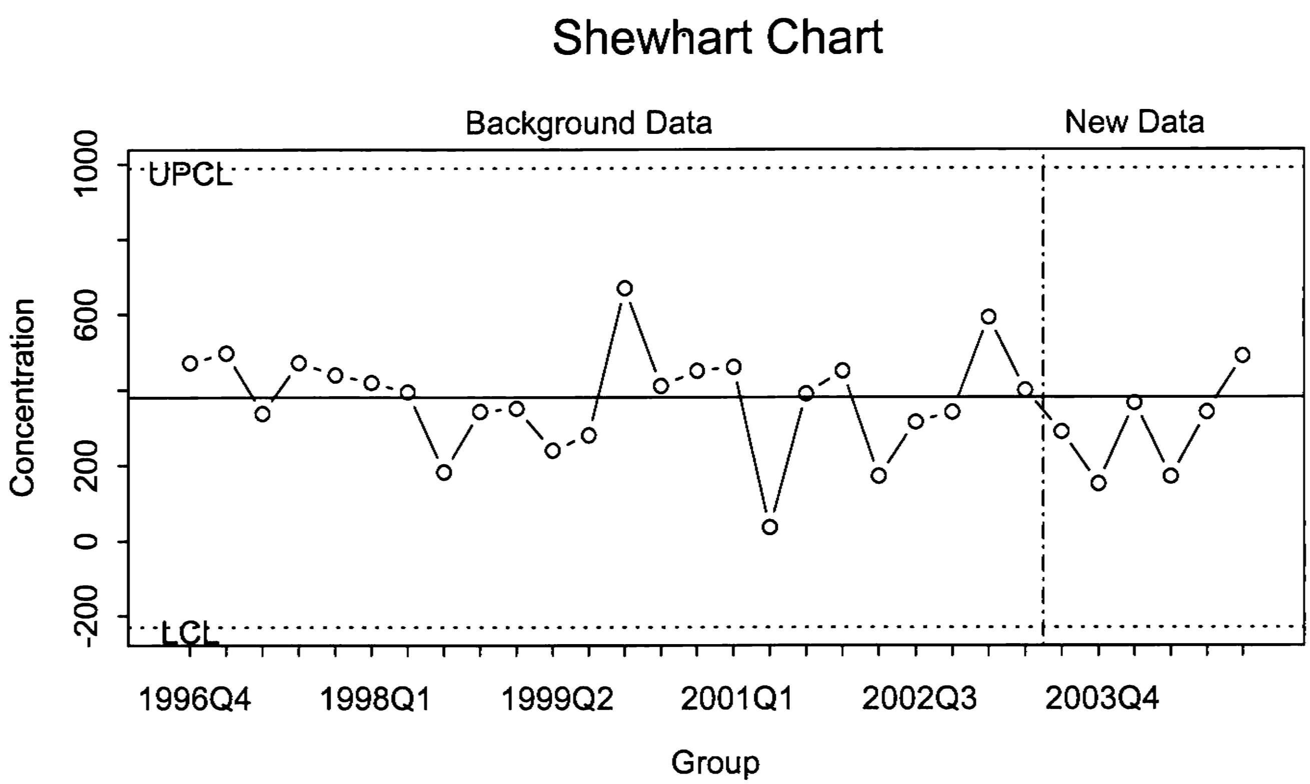
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-85M
Sulfate as SO4
mg/l





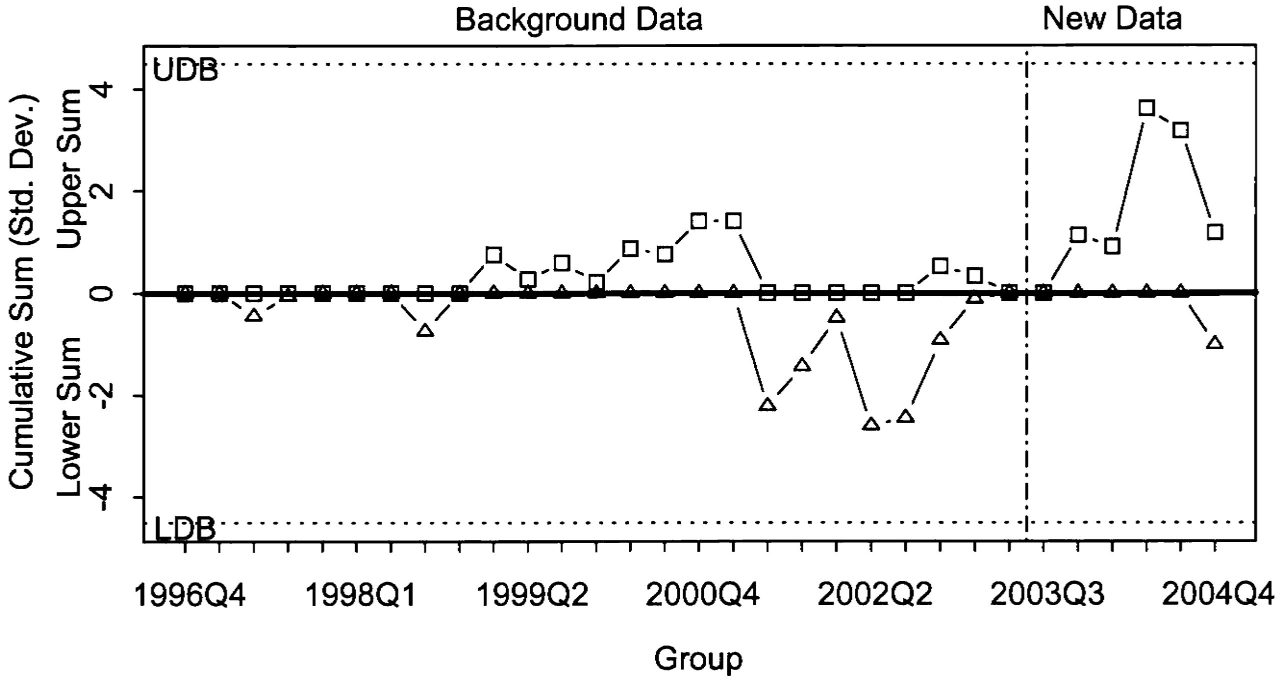
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-86D
Chloride
mg/l

CUSUM CHART



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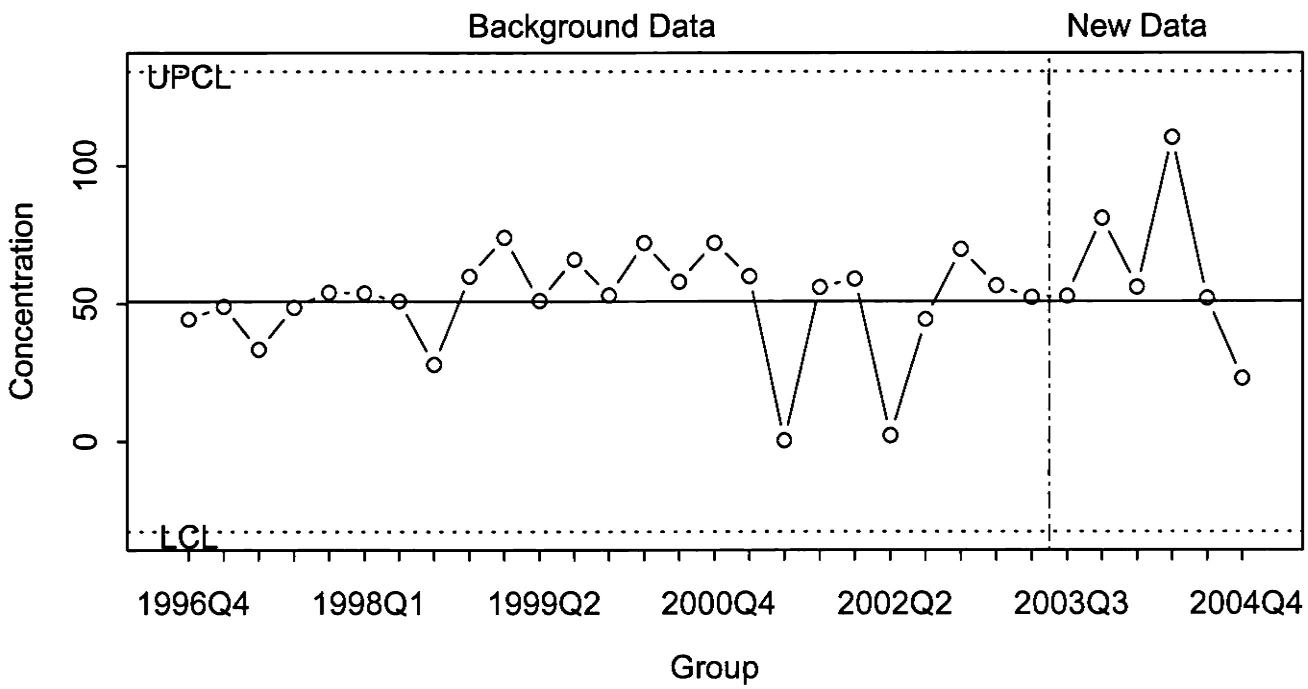


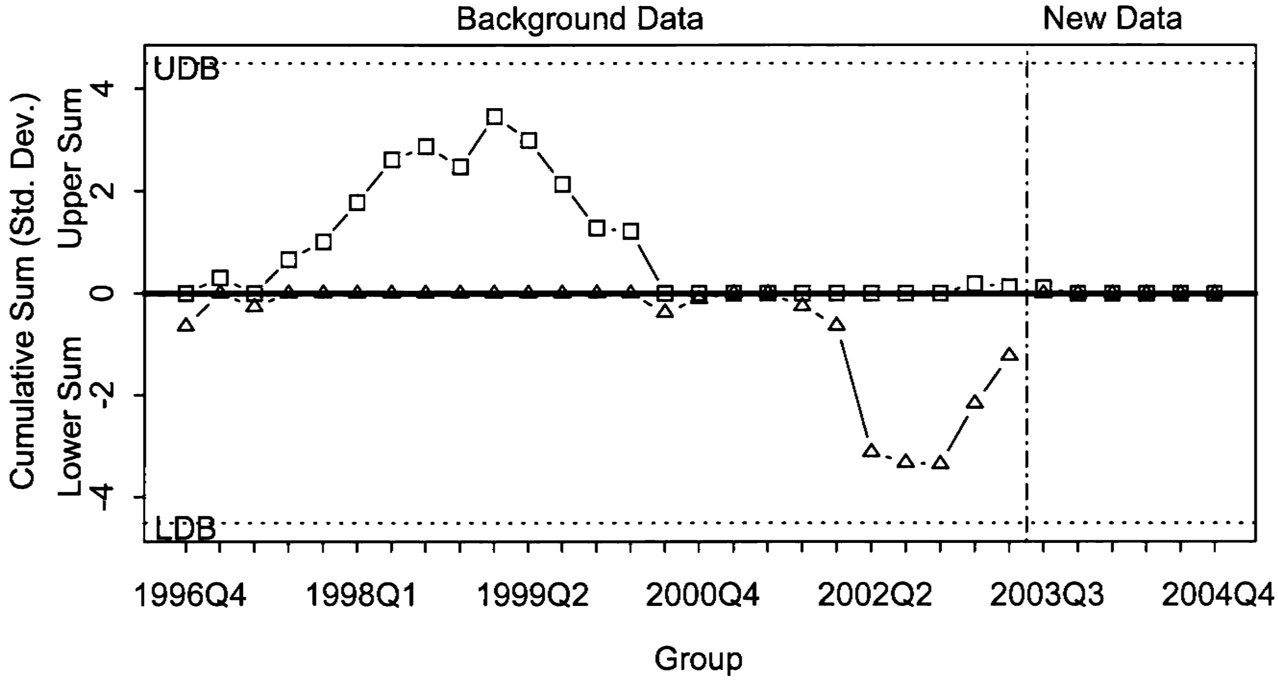
GEOMEGA

5/18/05

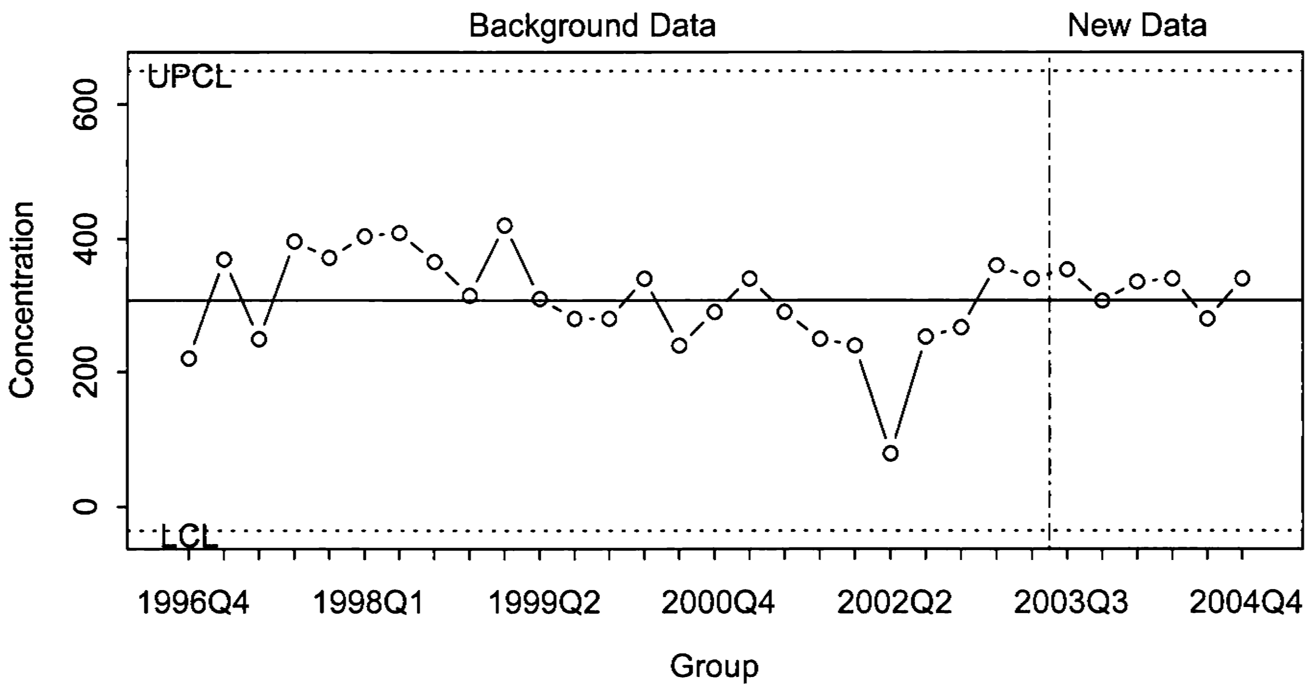
C03302C
Olin-Wilmington

GW-86D
Nitrogen, Ammonia
mg/l

CUSUM CHART



Shewhart Chart

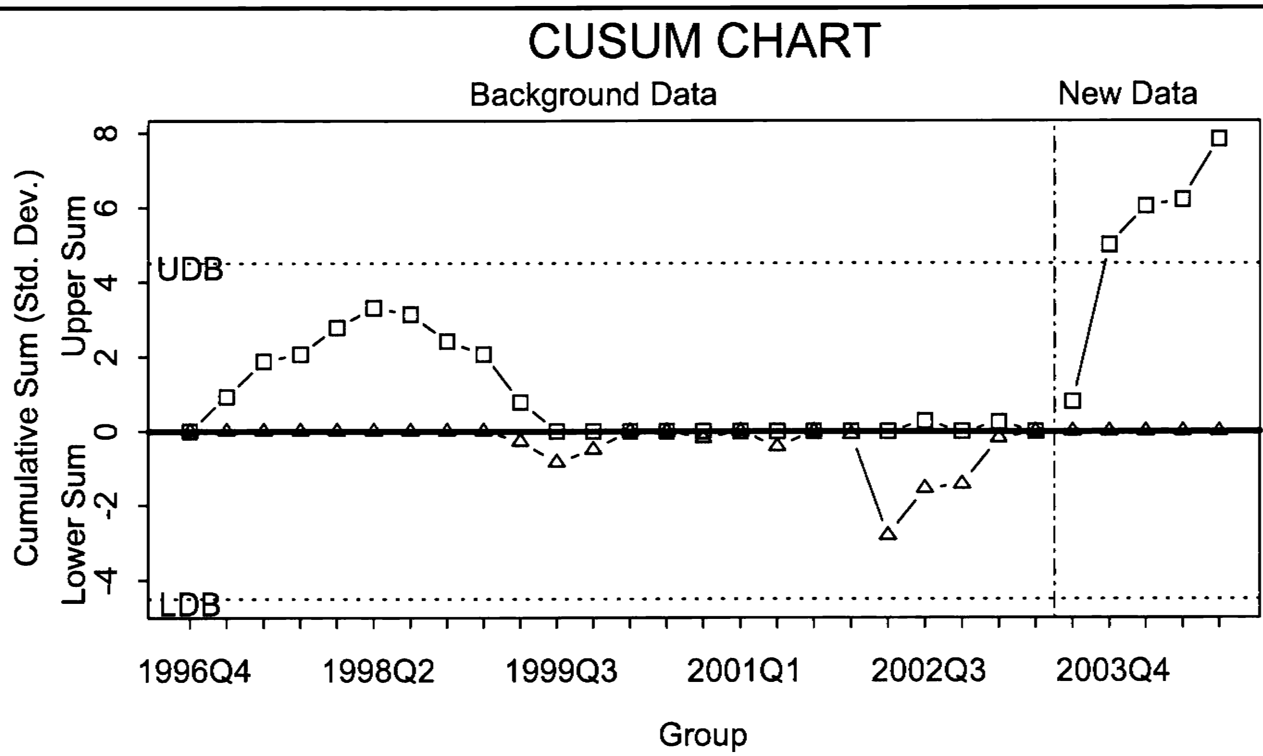


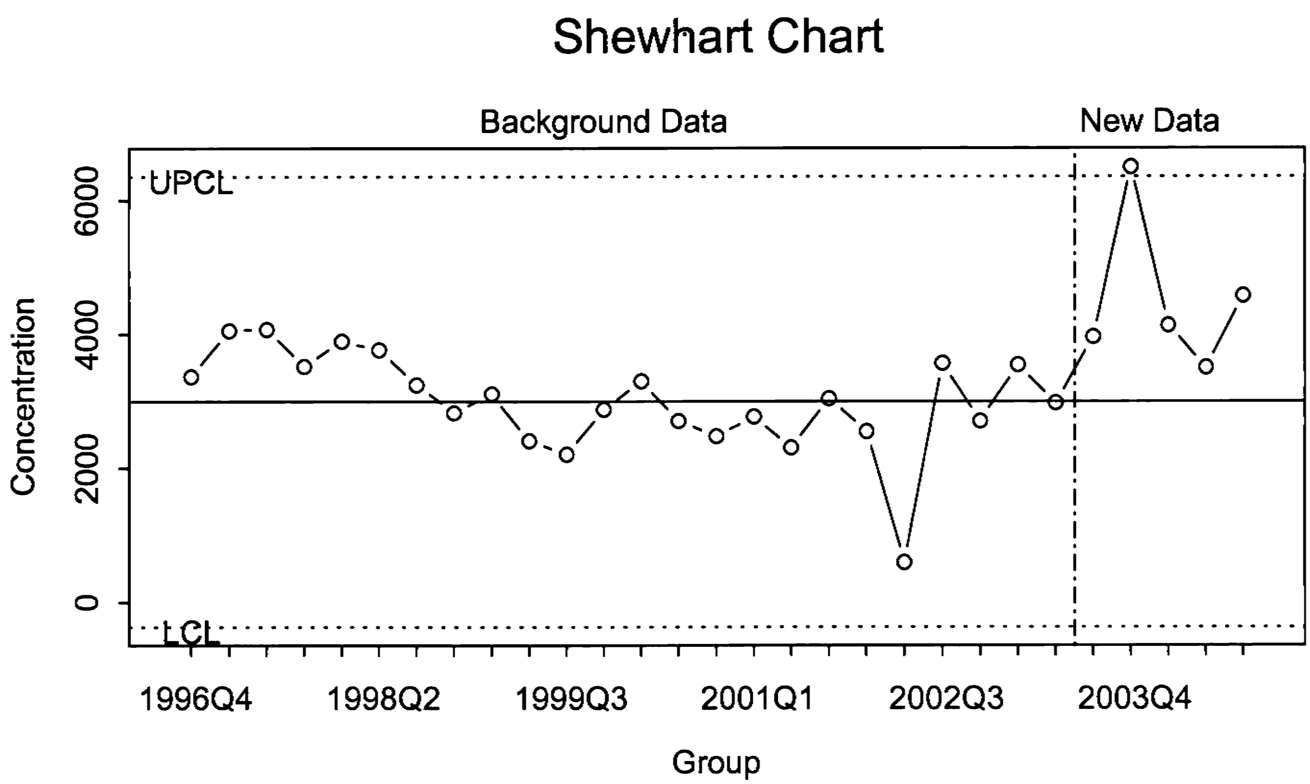
GEOMEGA

5/18/05

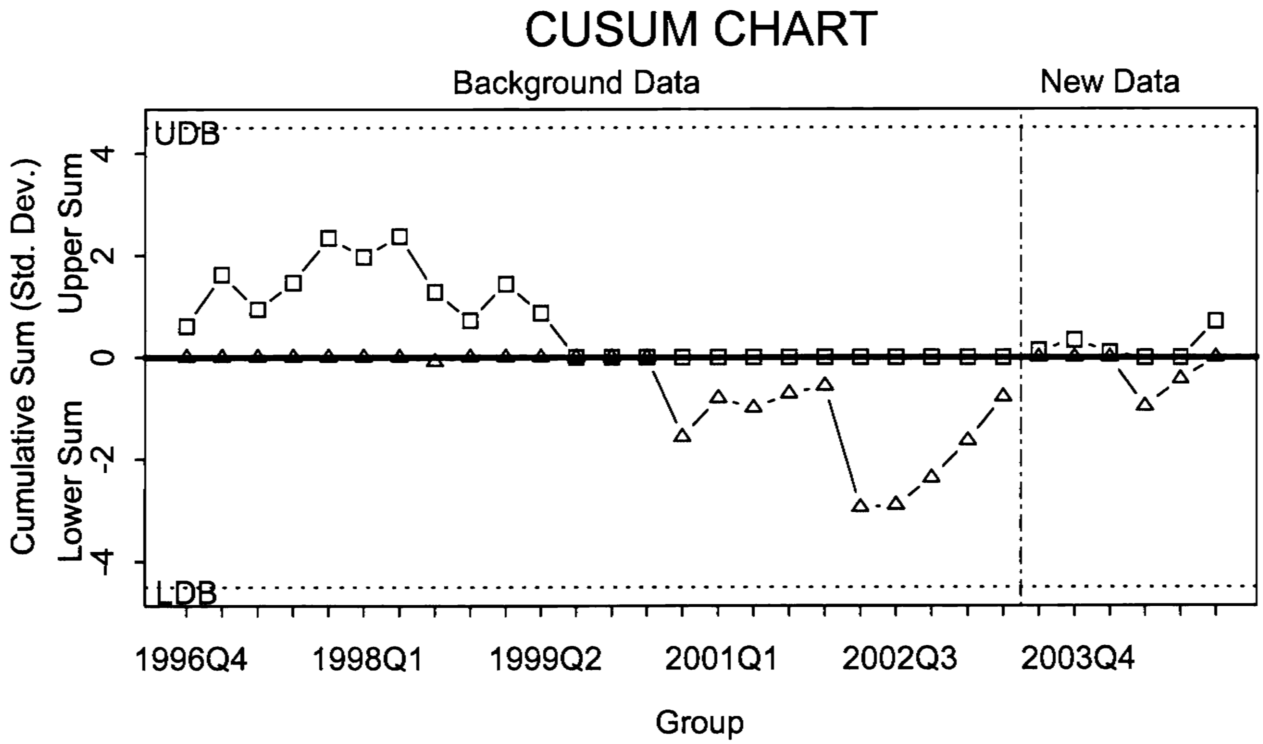
C03302C
Olin-Wilmington

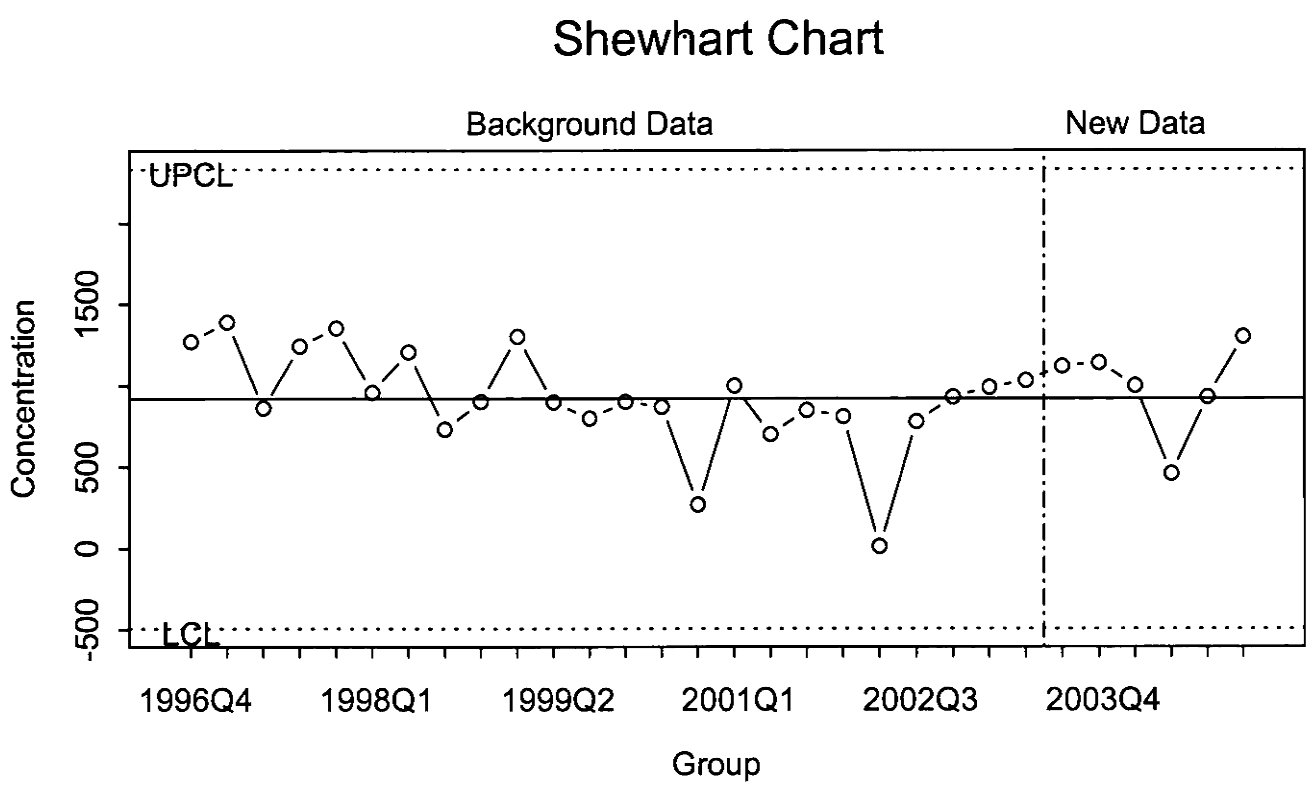
GW-86D
Sodium, Dissolved
mg/l





GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-86D Specific Conductance umhos/cm	



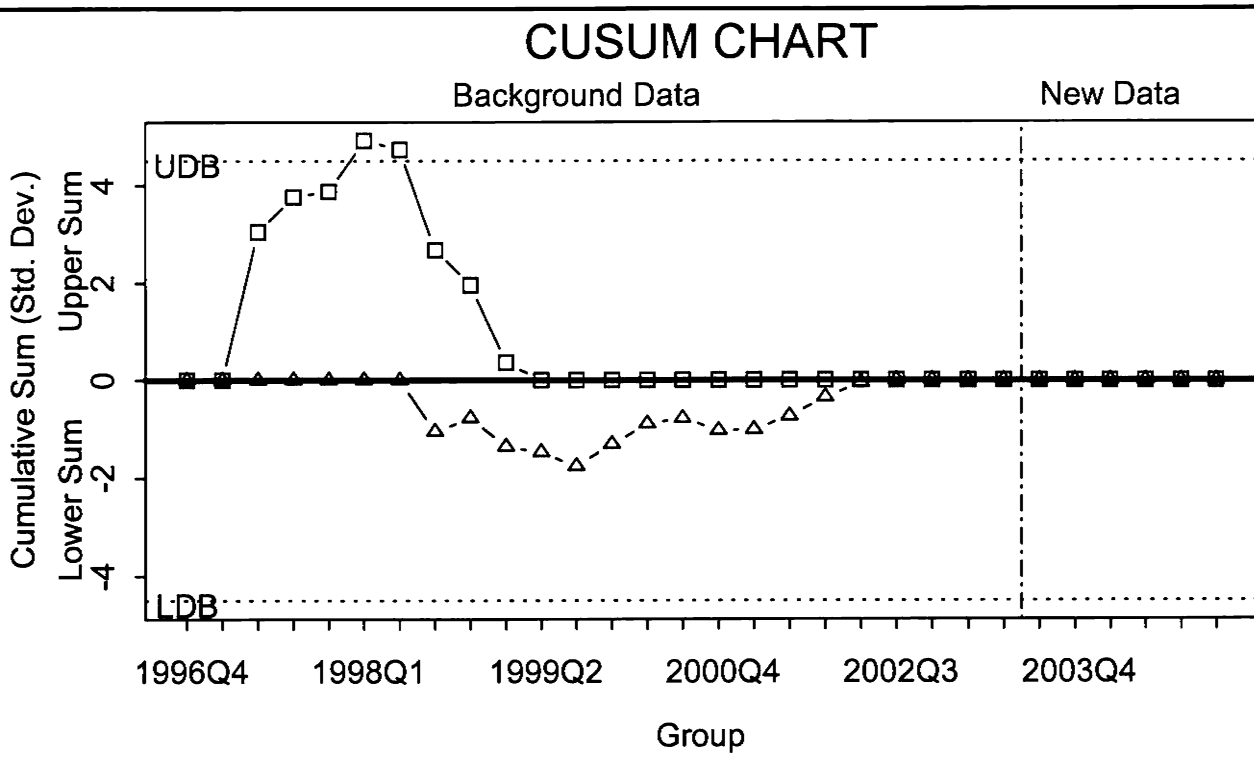


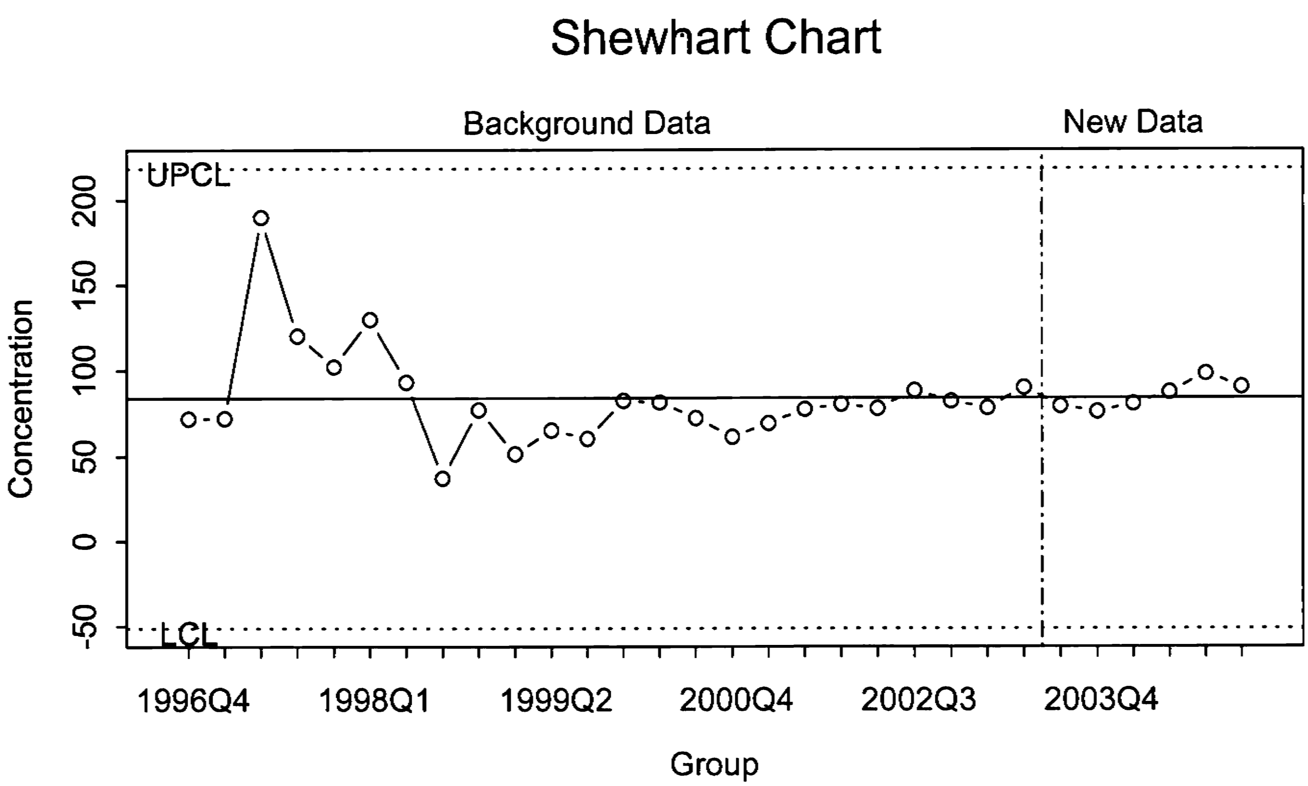
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-86D
Sulfate as SO4
mg/l





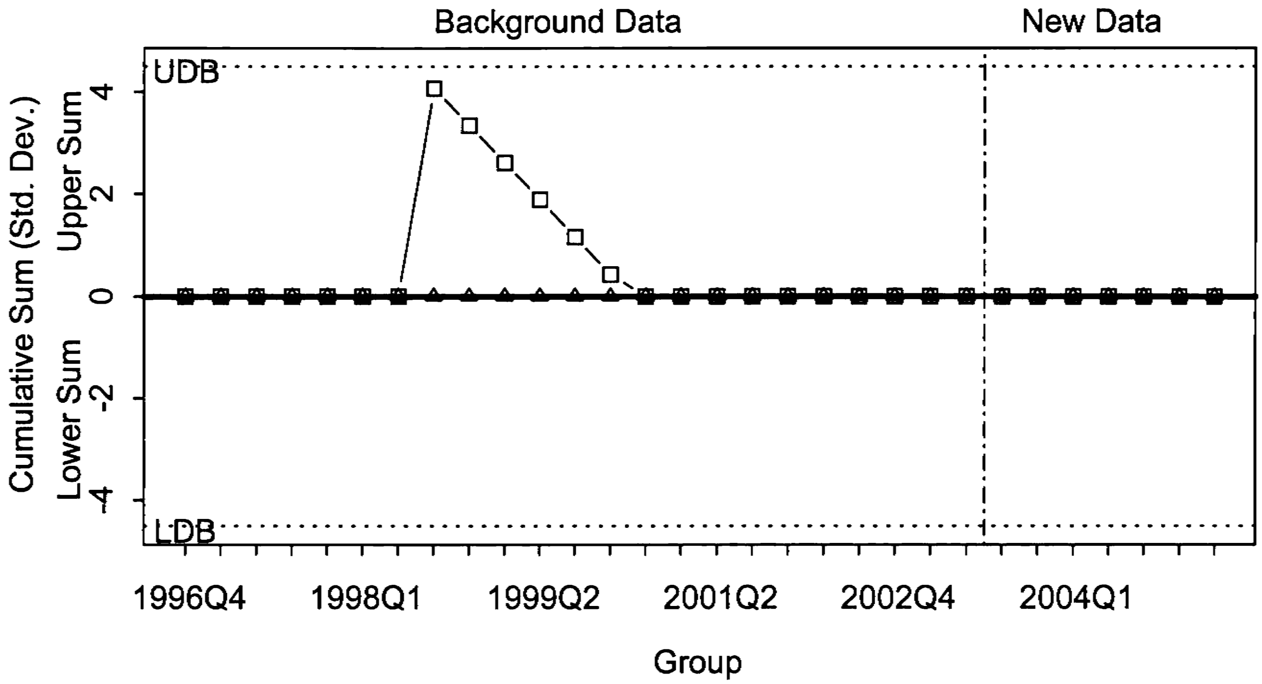
GEOMEGA

5/18/05

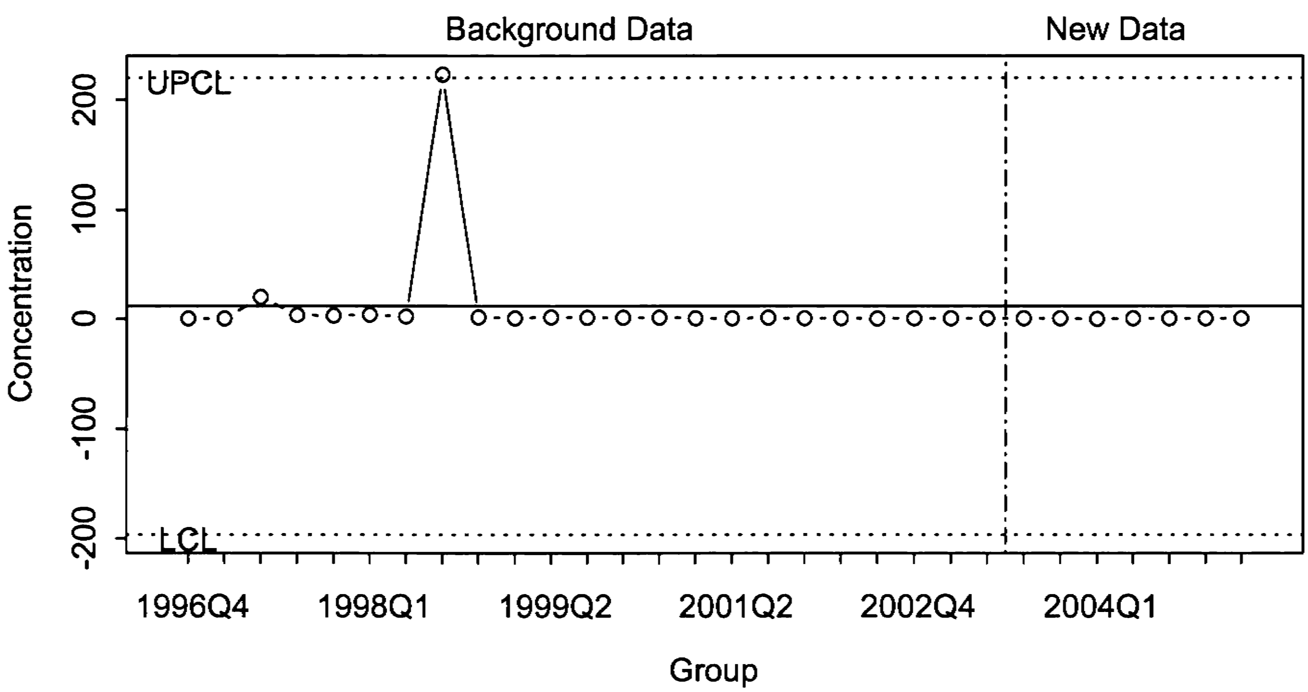
C03302C
Olin-Wilmington

GW-86M
Chloride
mg/l

CUSUM CHART



Shewhart Chart



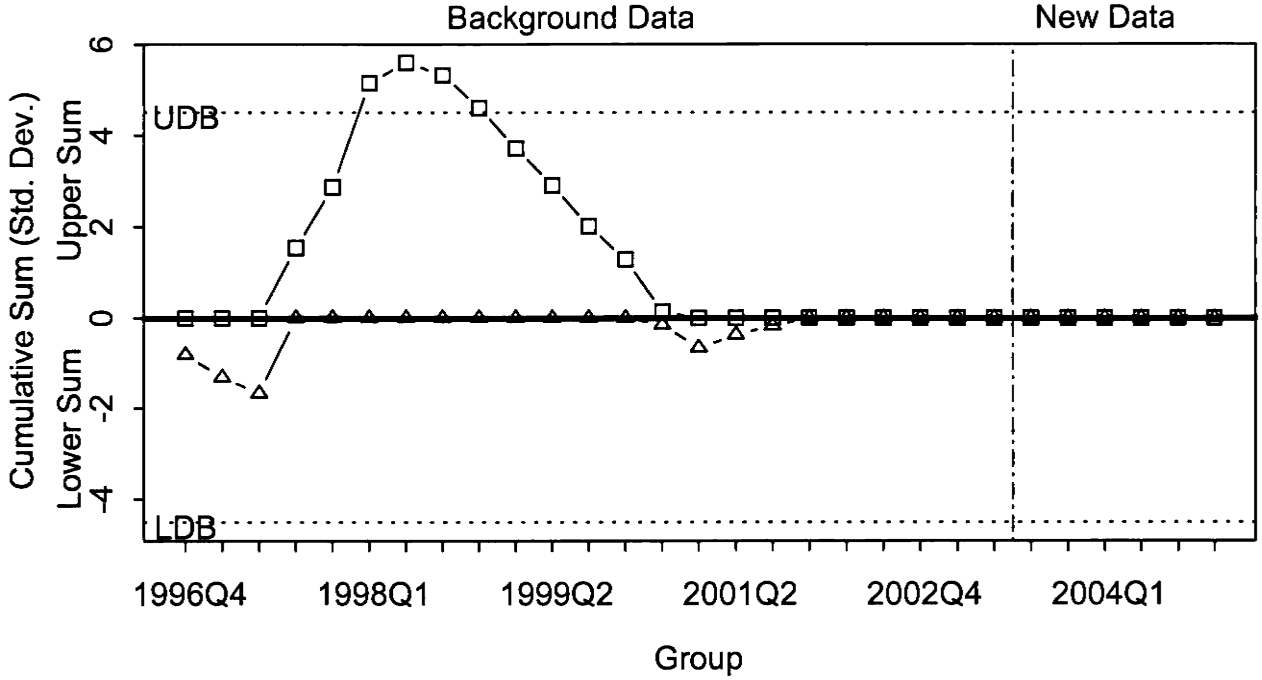
GEOMEGA

5/18/05

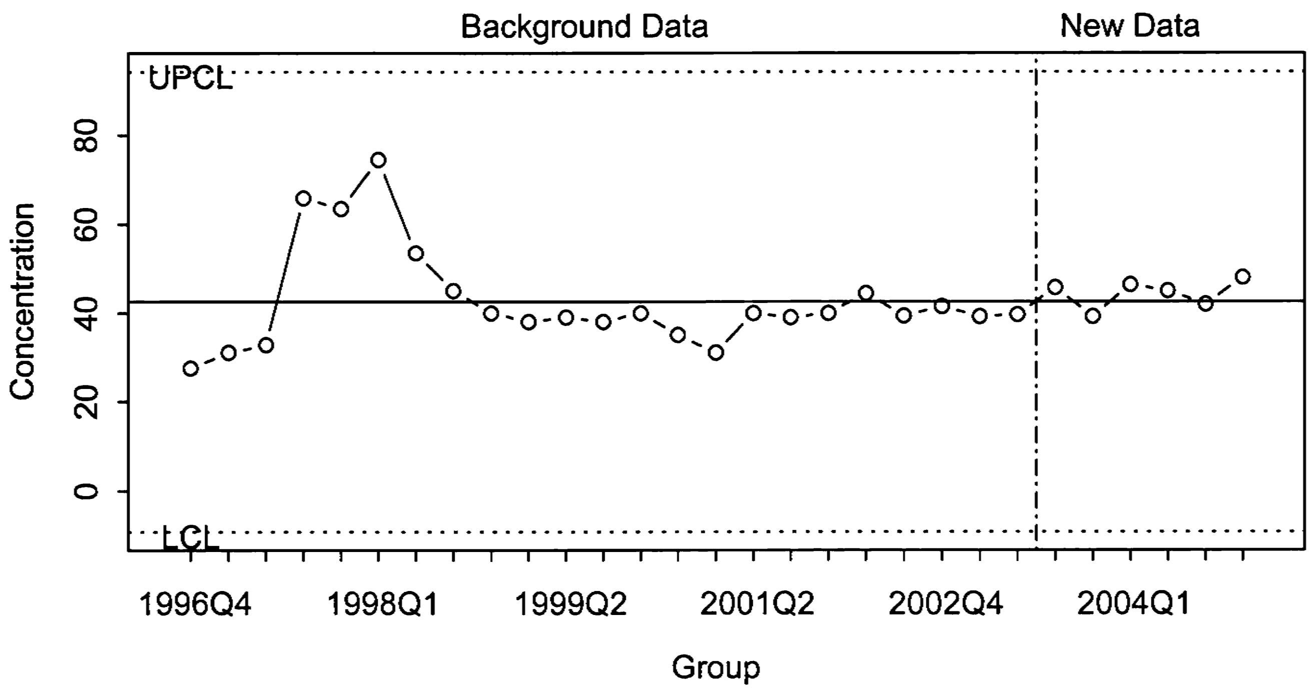
C03302C
Olin-Wilmington

GW-86M
Nitrogen, Ammonia
mg/l

CUSUM CHART



Shewhart Chart

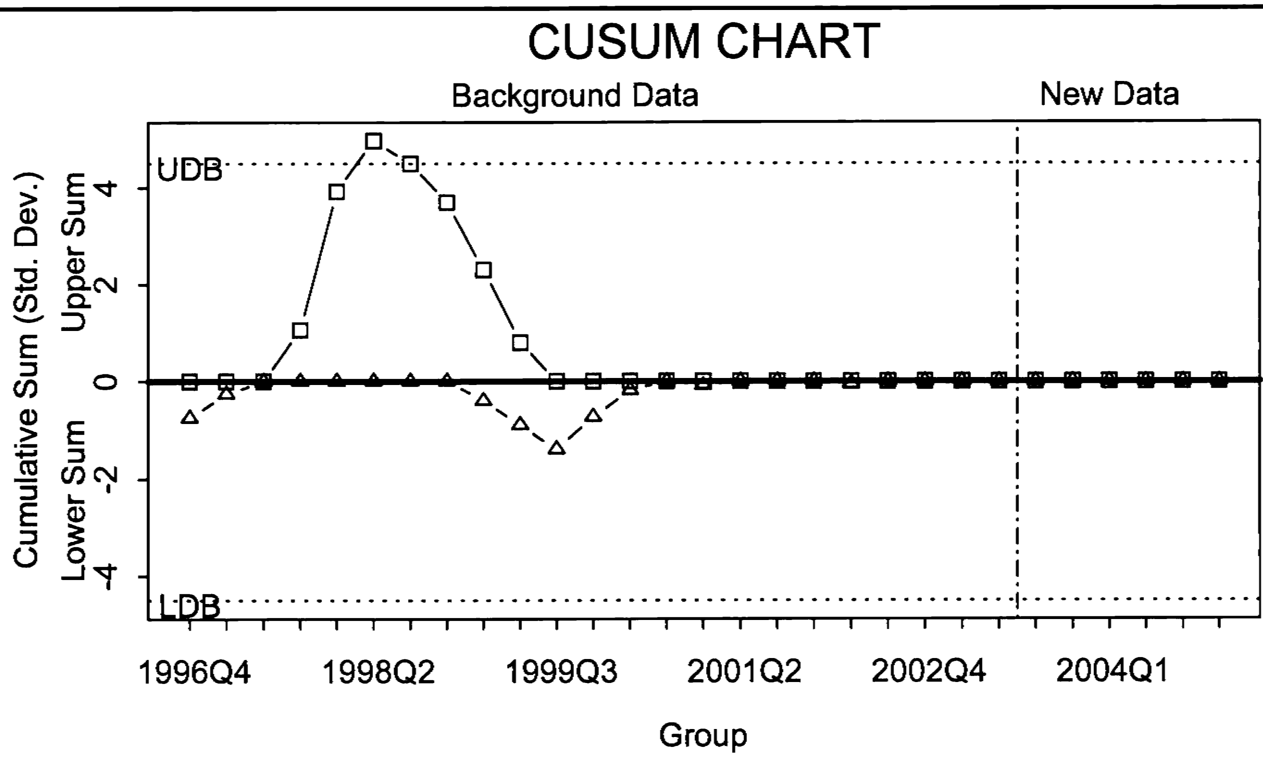


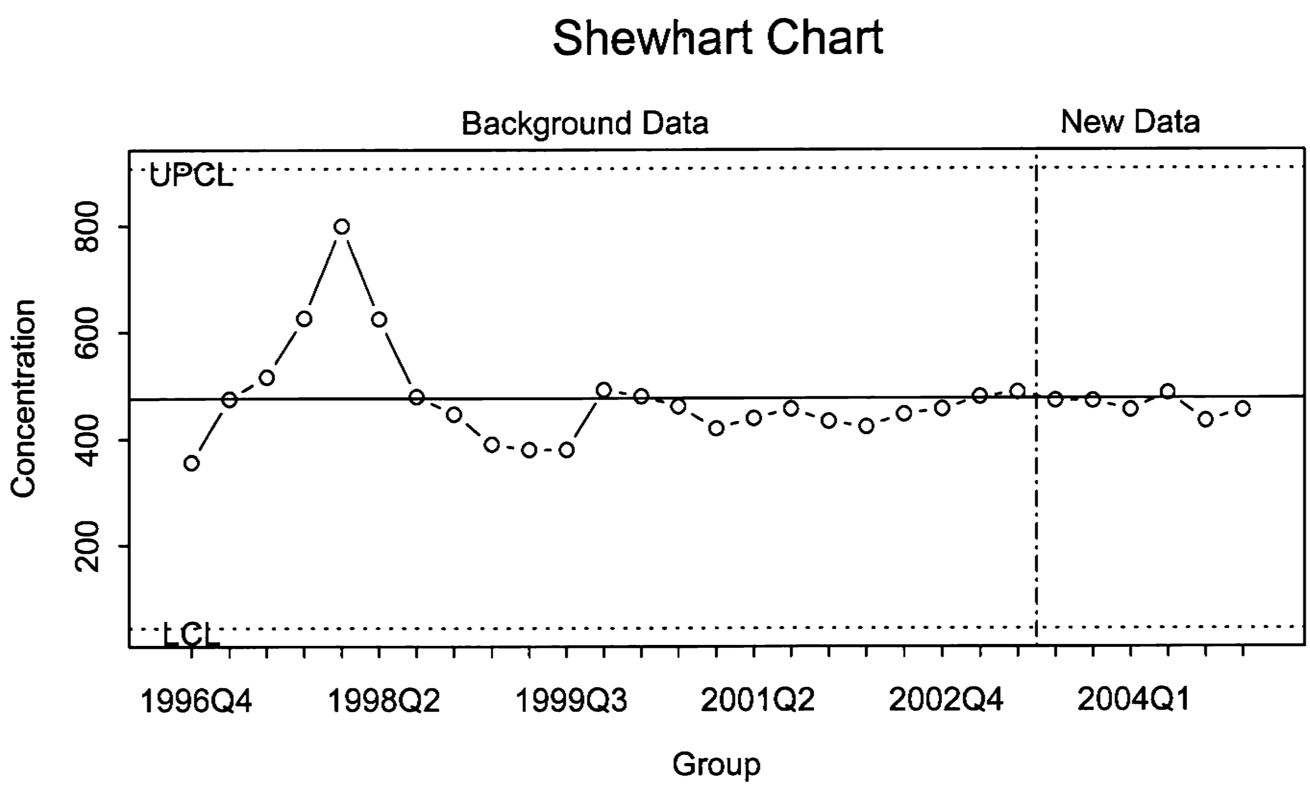
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-86M
Sodium, Dissolved
mg/l



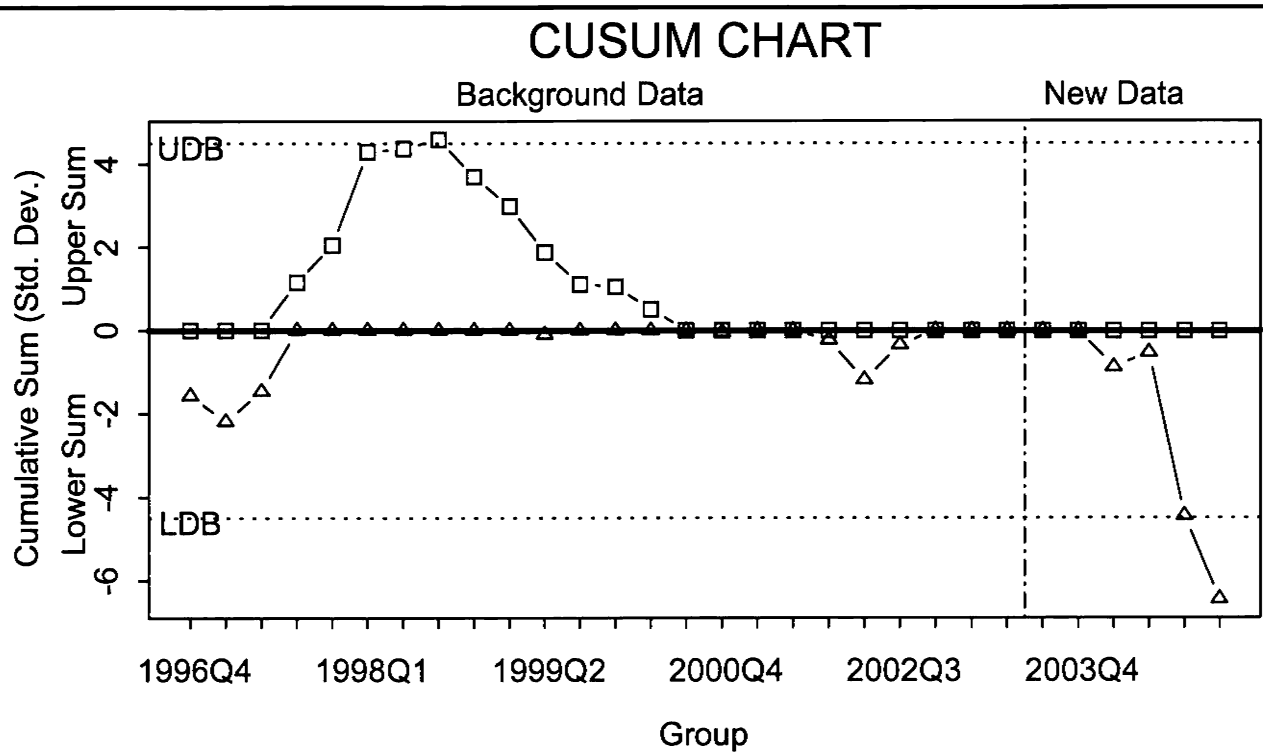


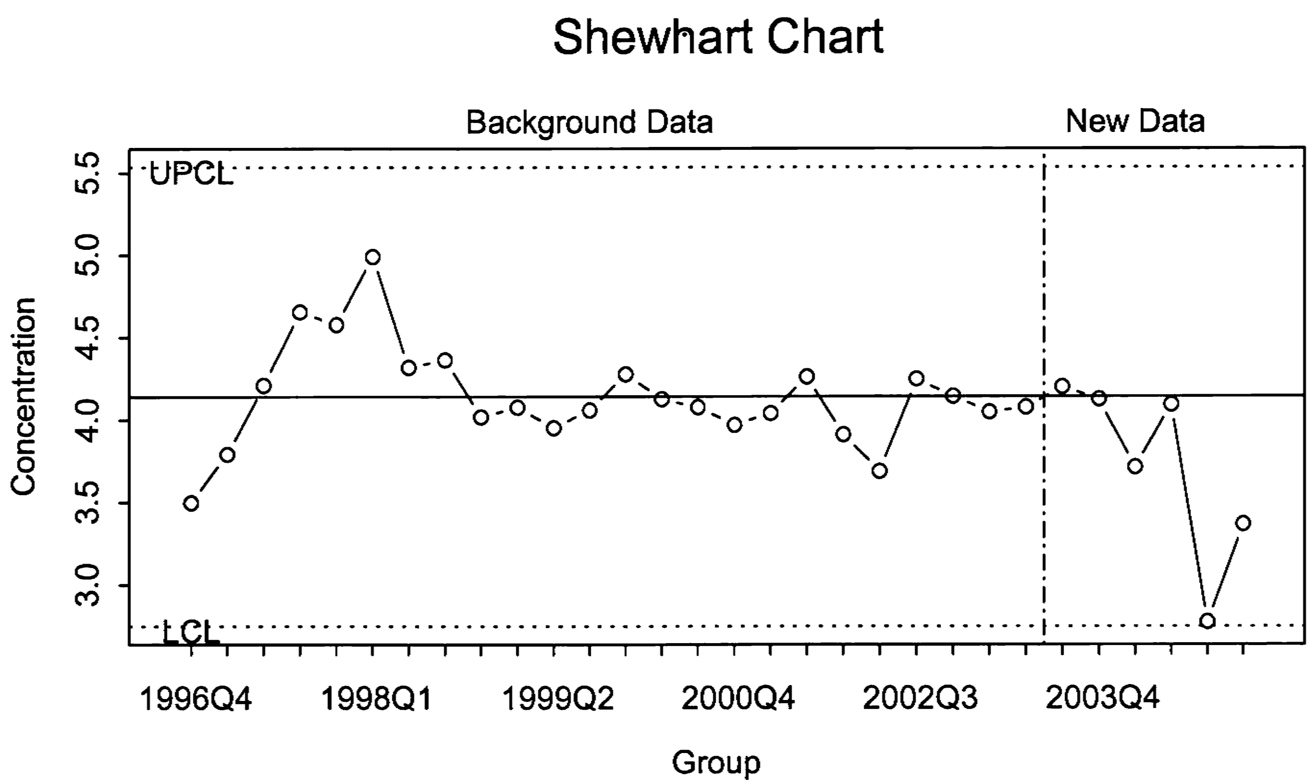
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-86M
Specific Conductance
umhos/cm



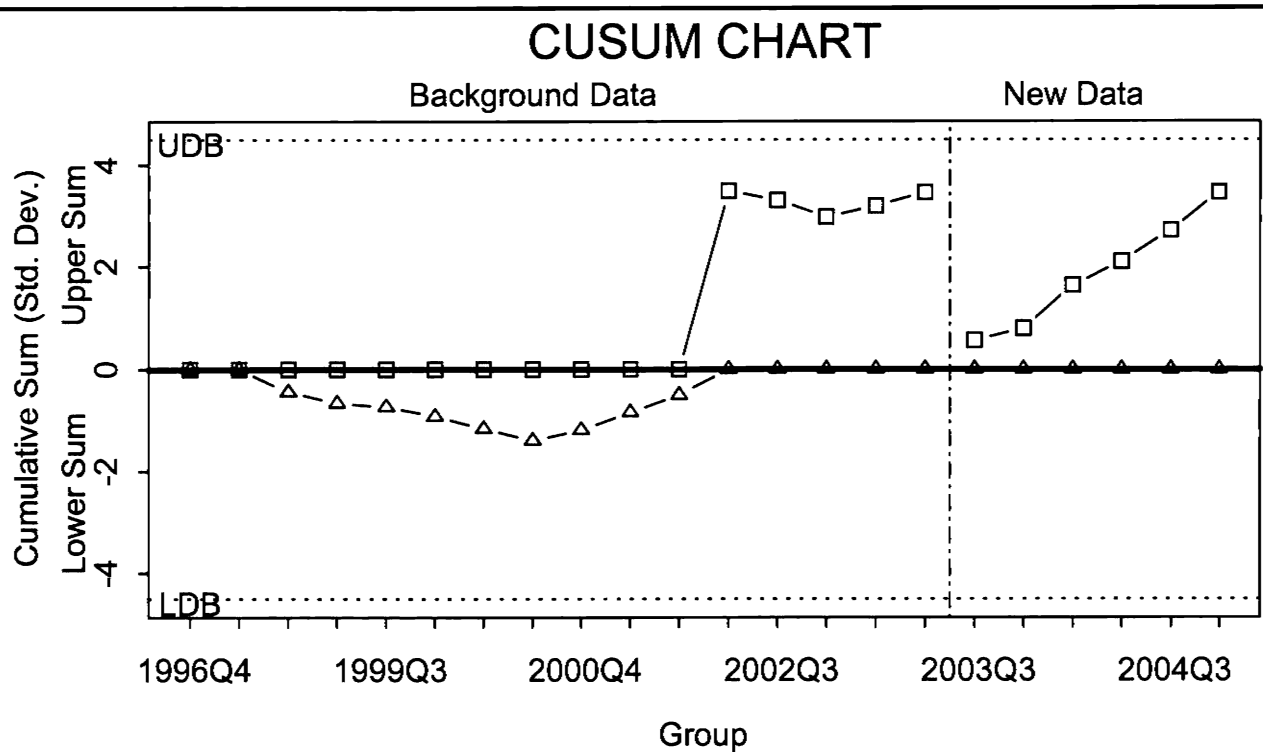


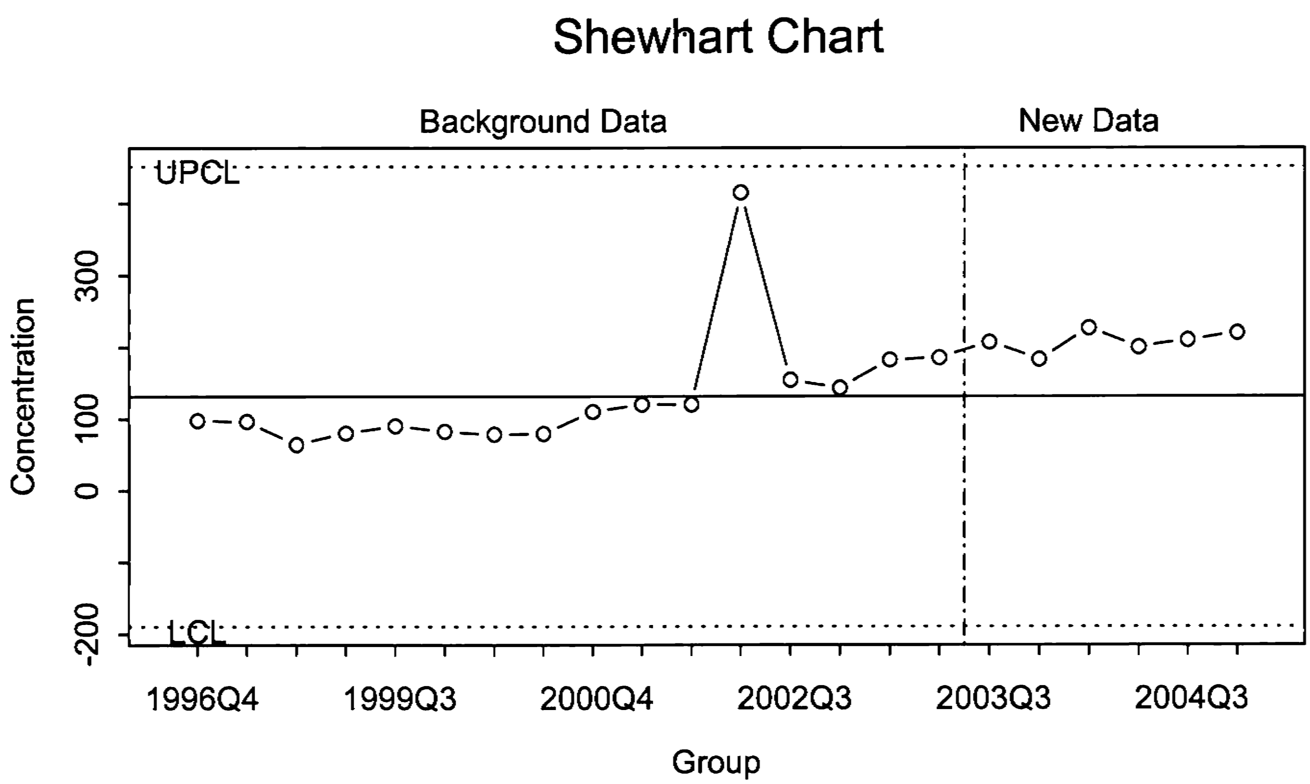
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-86M
Sulfate as SO4
Log(mg/l)



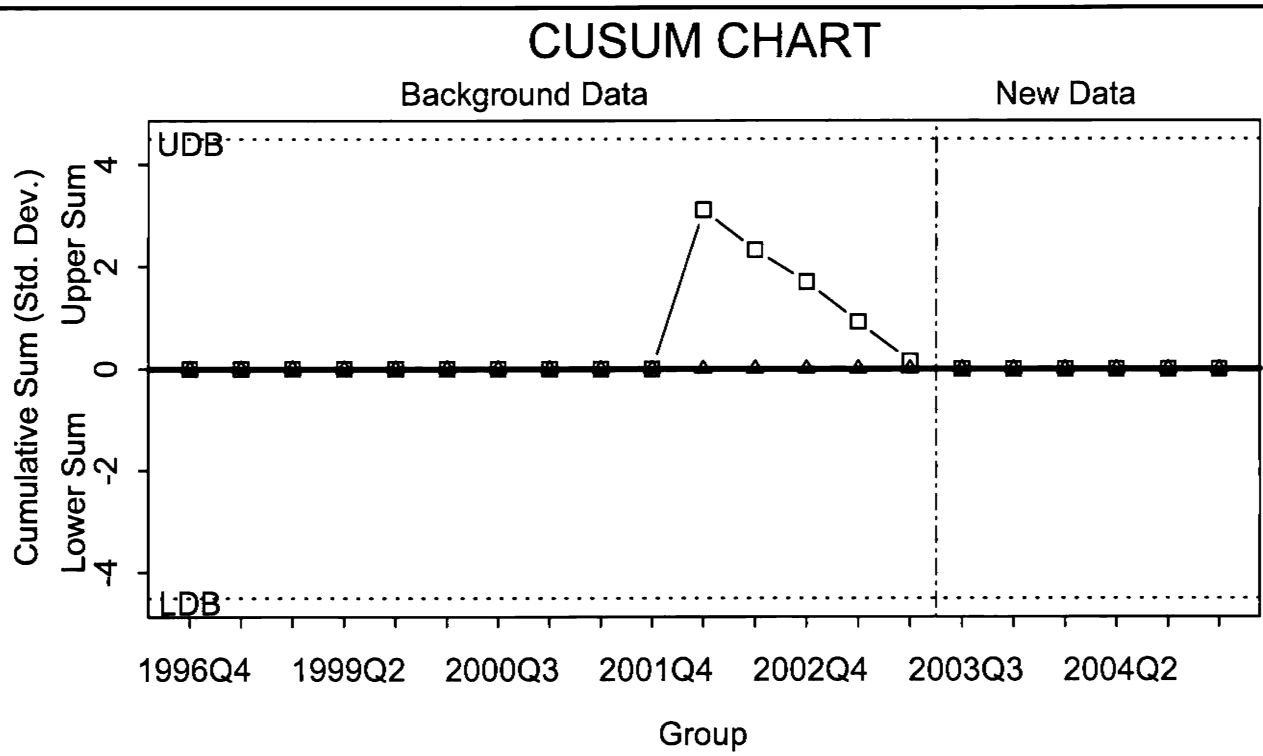


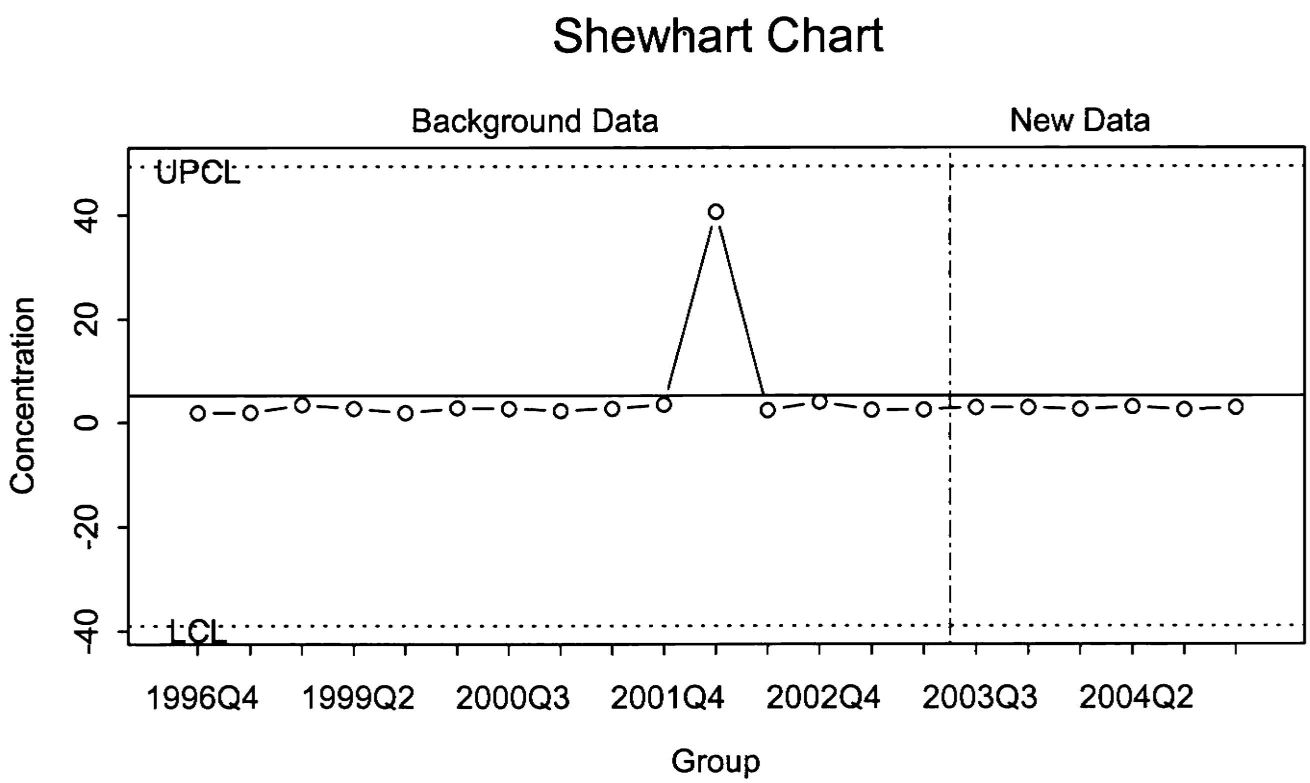
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-86S
Chloride
mg/l



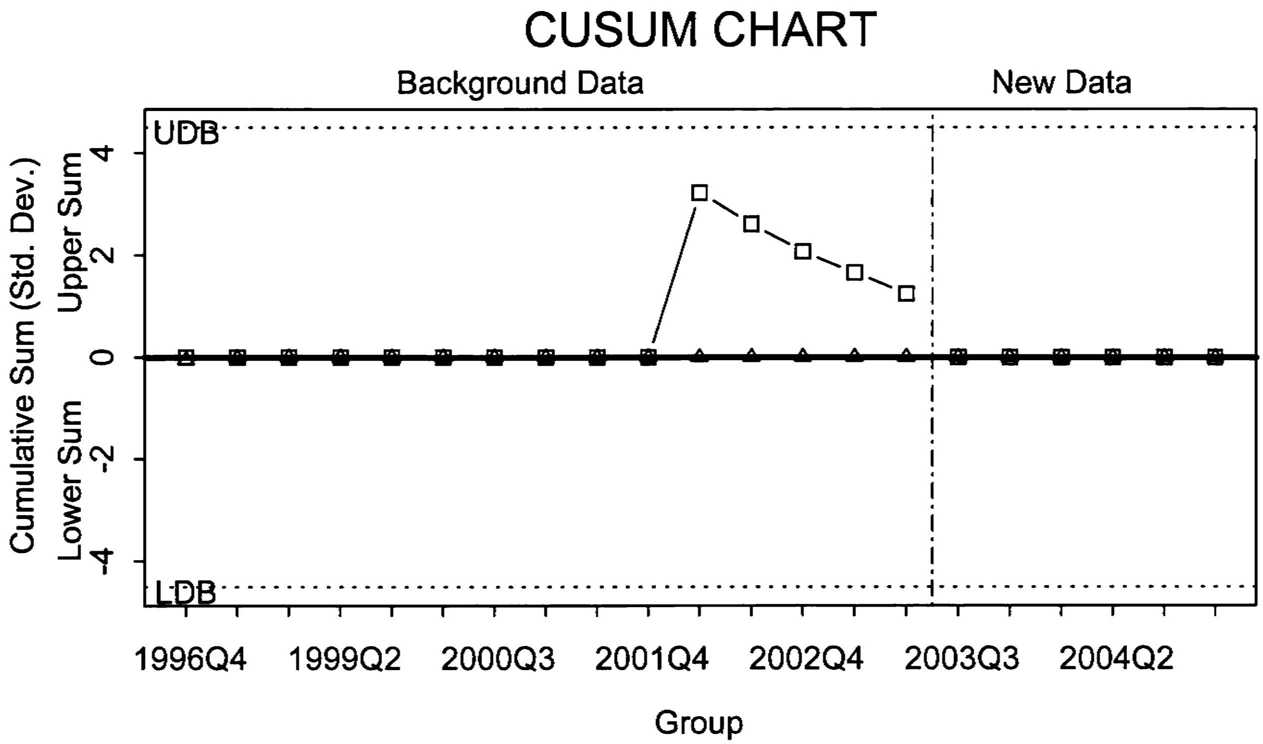


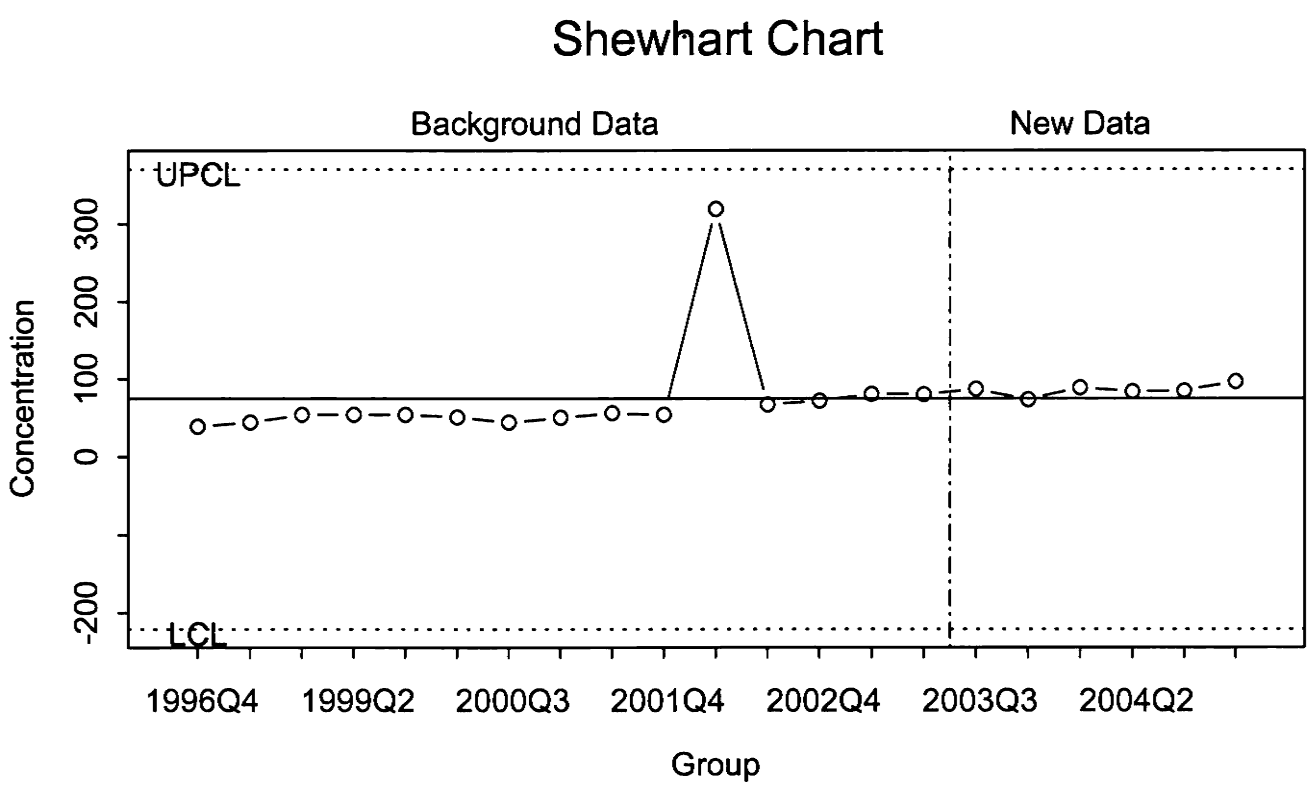
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-86S
Nitrogen, Ammonia
mg/l



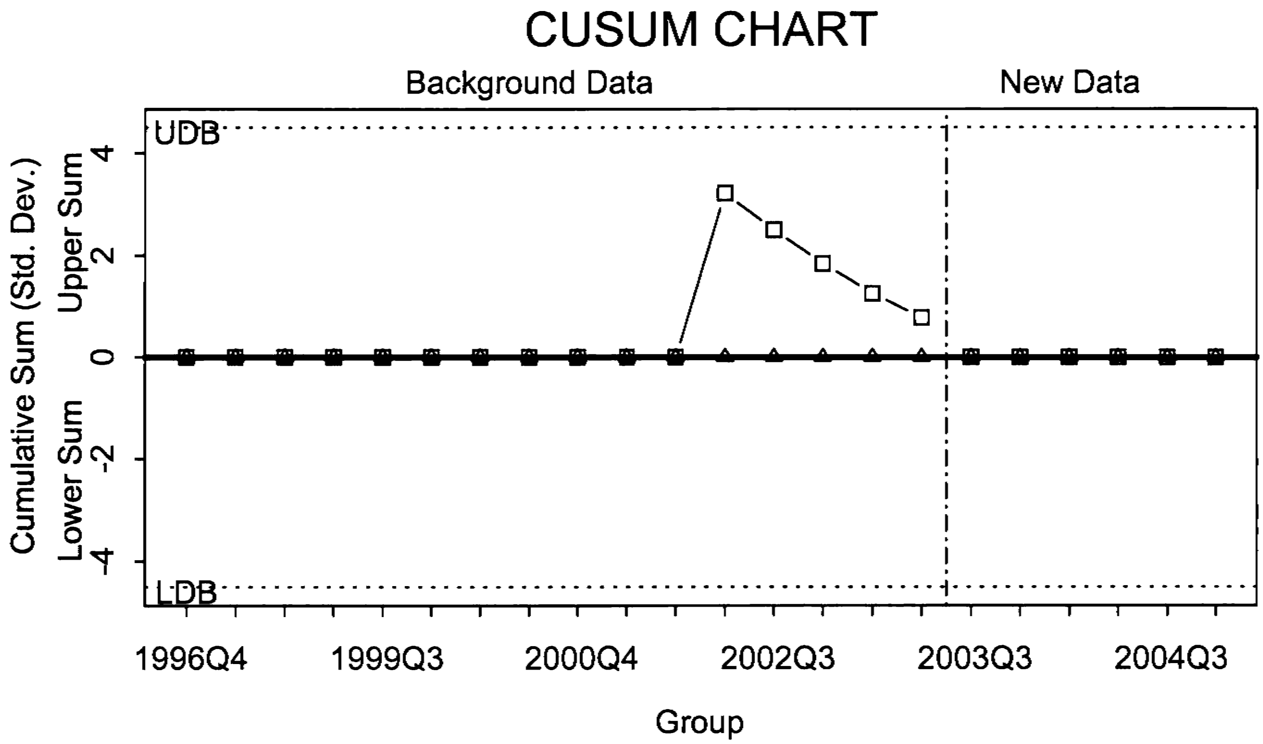


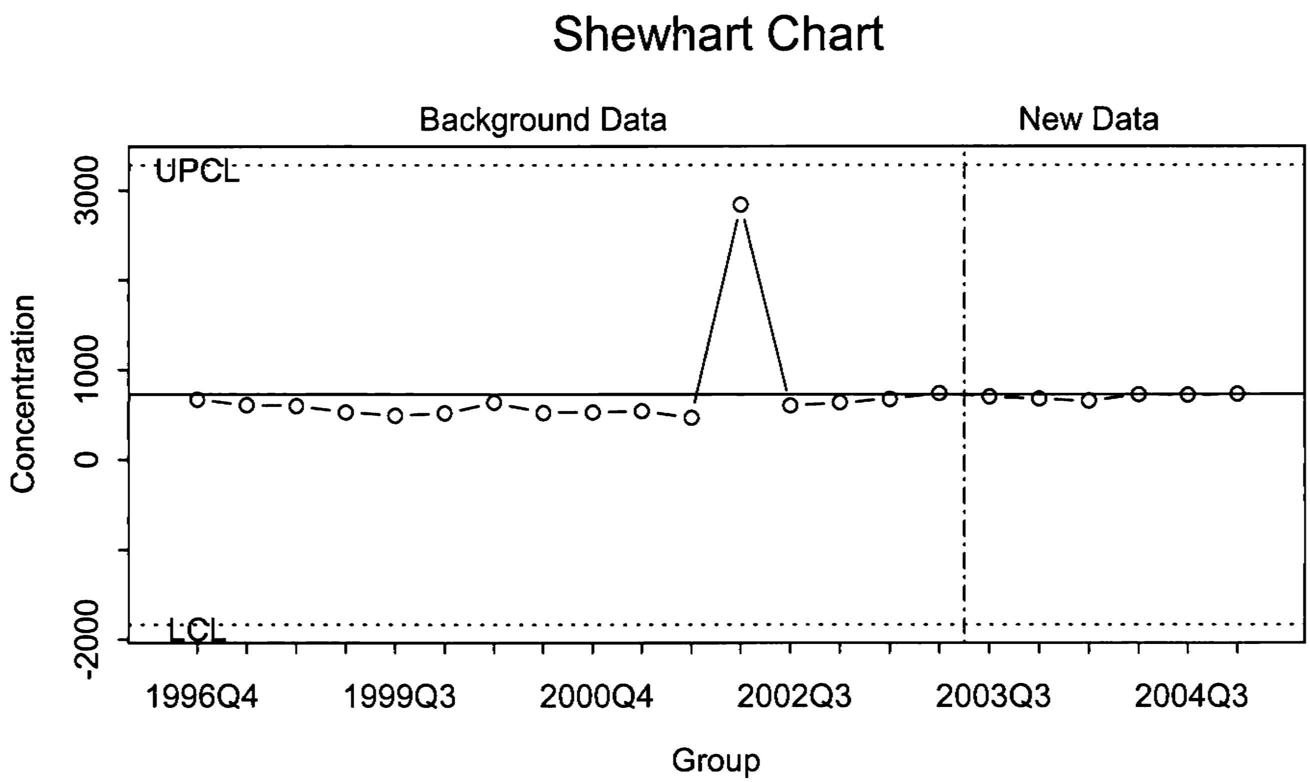
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-86S
Sodium, Dissolved
mg/l





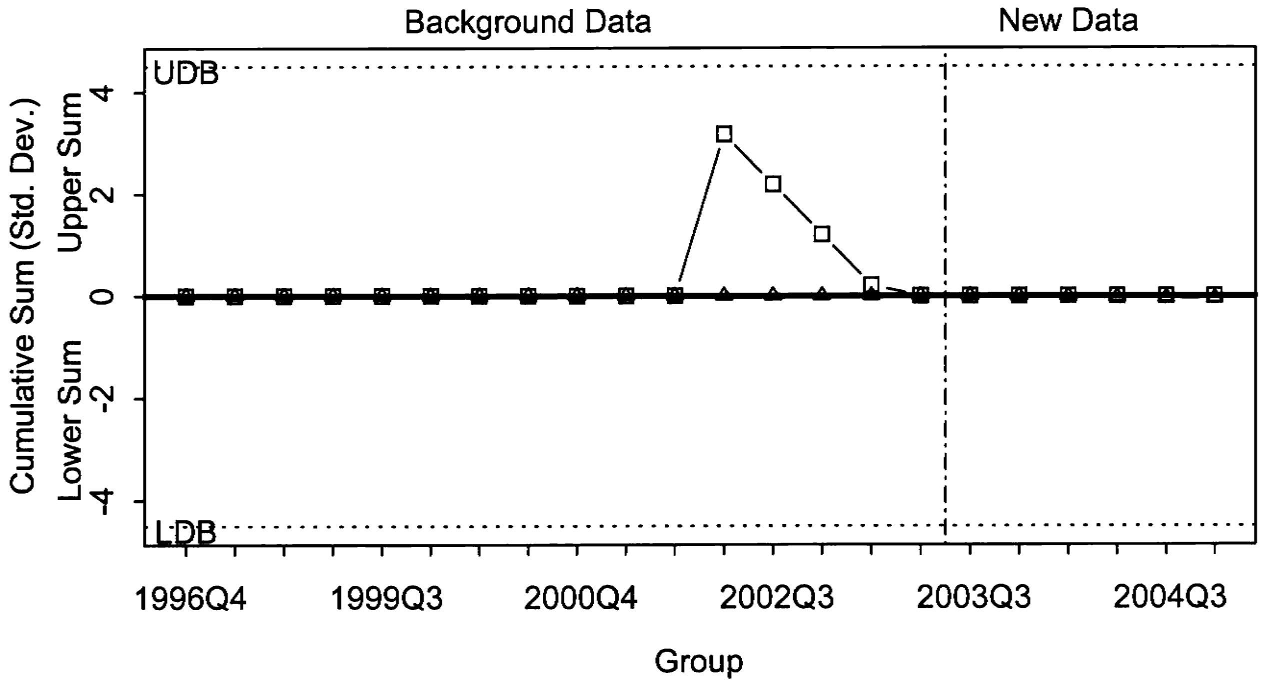
GEOMEGA

5/18/05

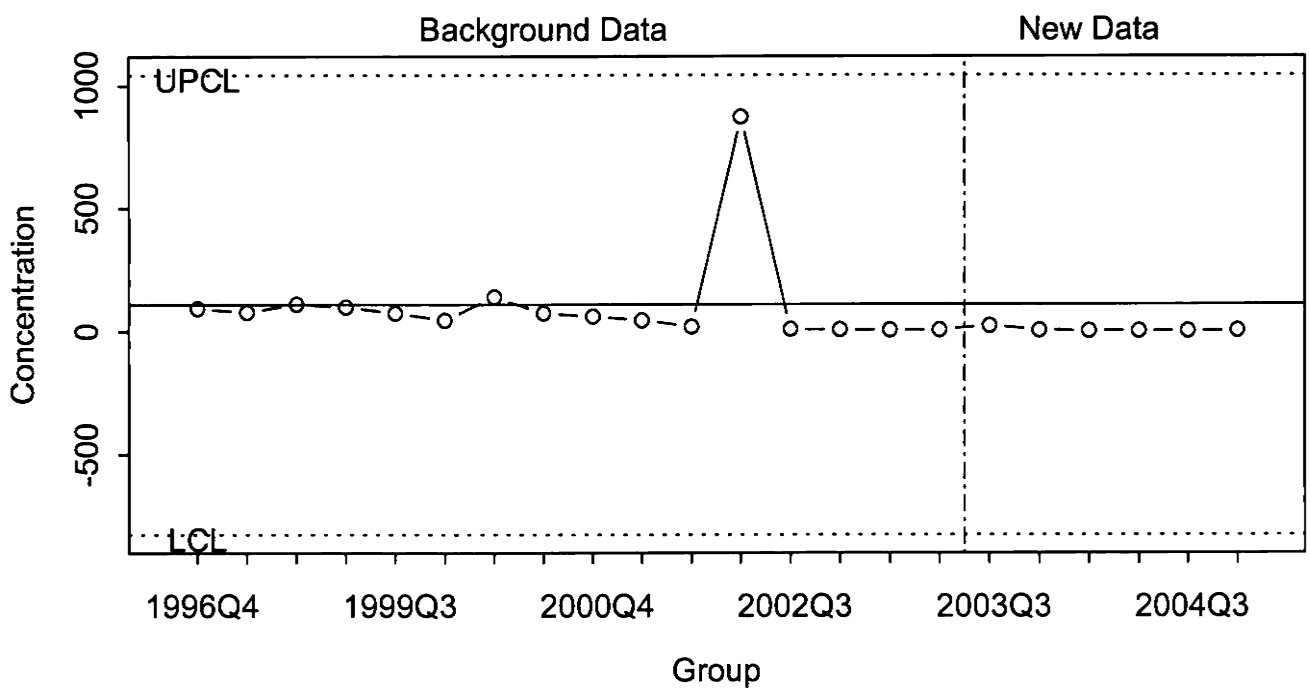
C03302C
Olin-Wilmington

GW-86S
Specific Conductance
umhos/cm

CUSUM CHART



Shewhart Chart



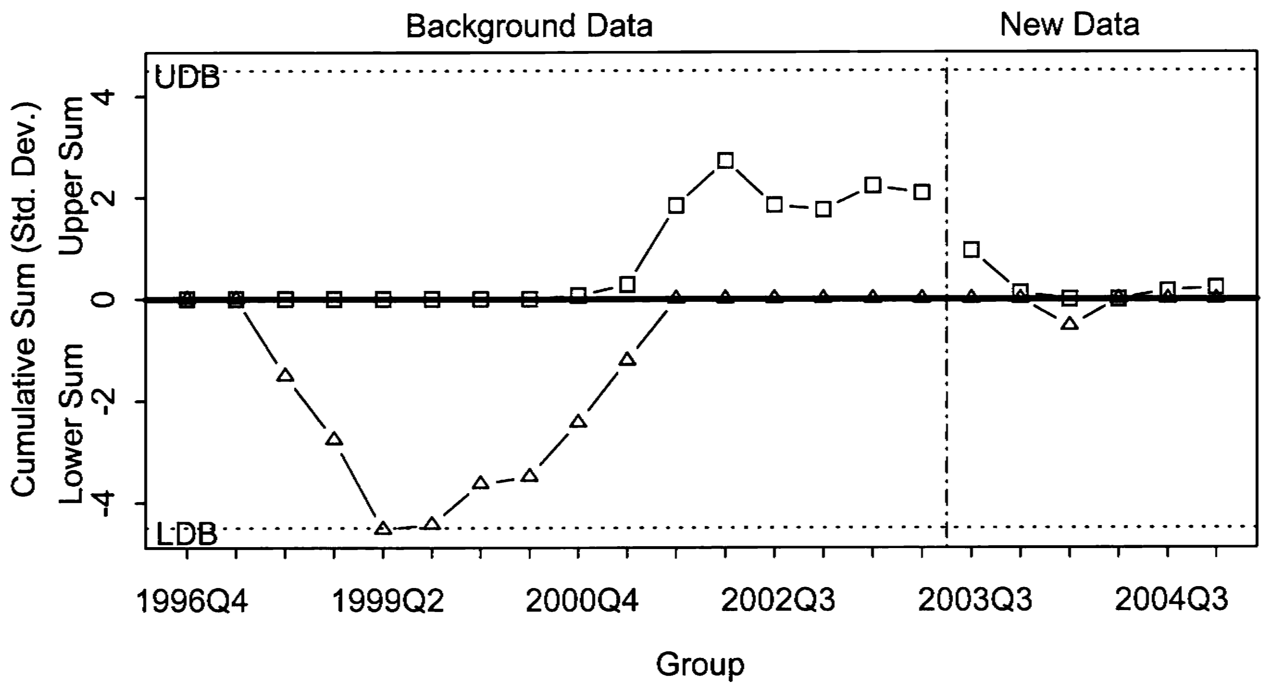
GEOMEGA

5/18/05

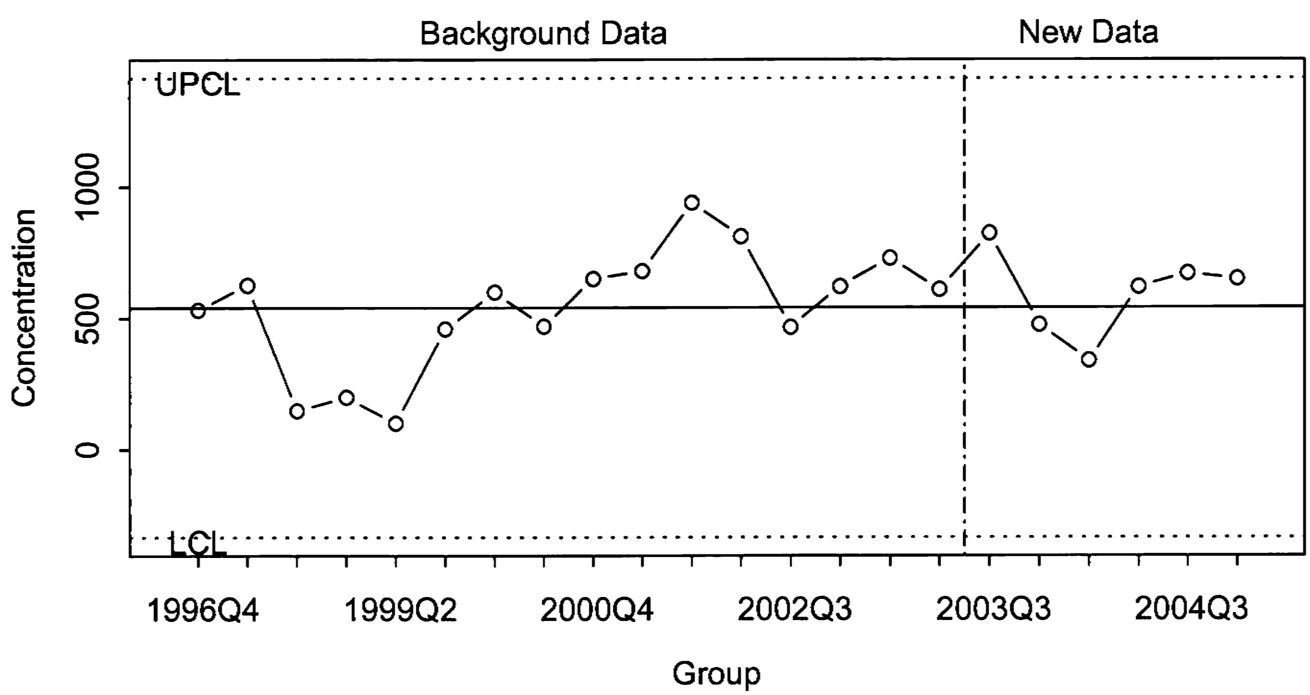
C03302C
Olin-Wilmington

GW-86S
Sulfate as SO4
mg/l

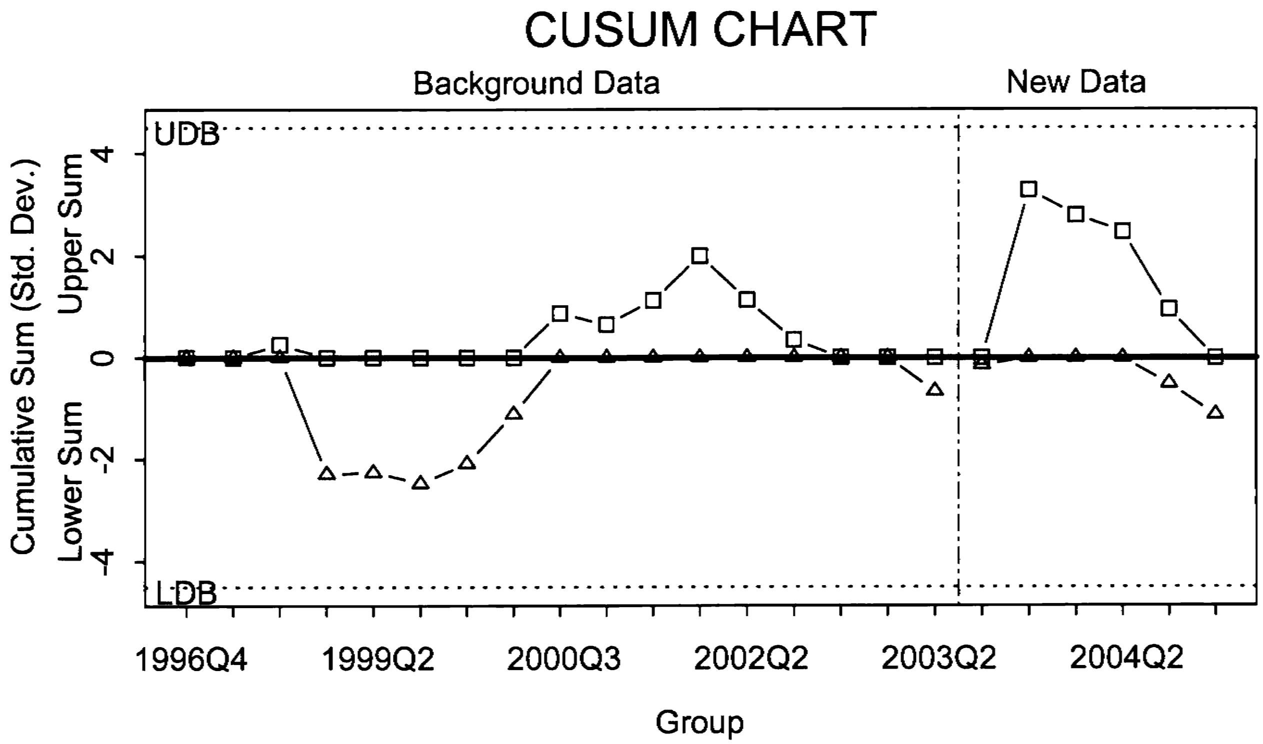
CUSUM CHART

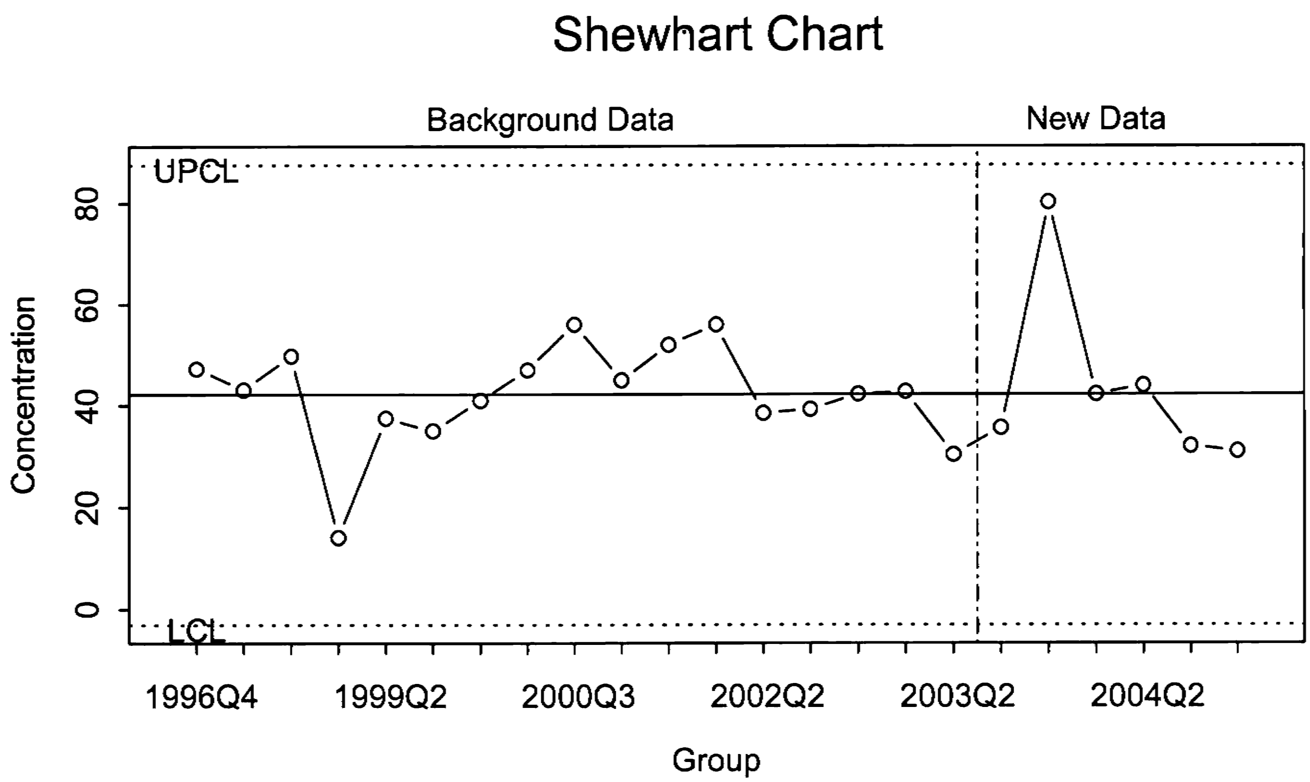


Shewhart Chart



GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-87D Chloride mg/l	



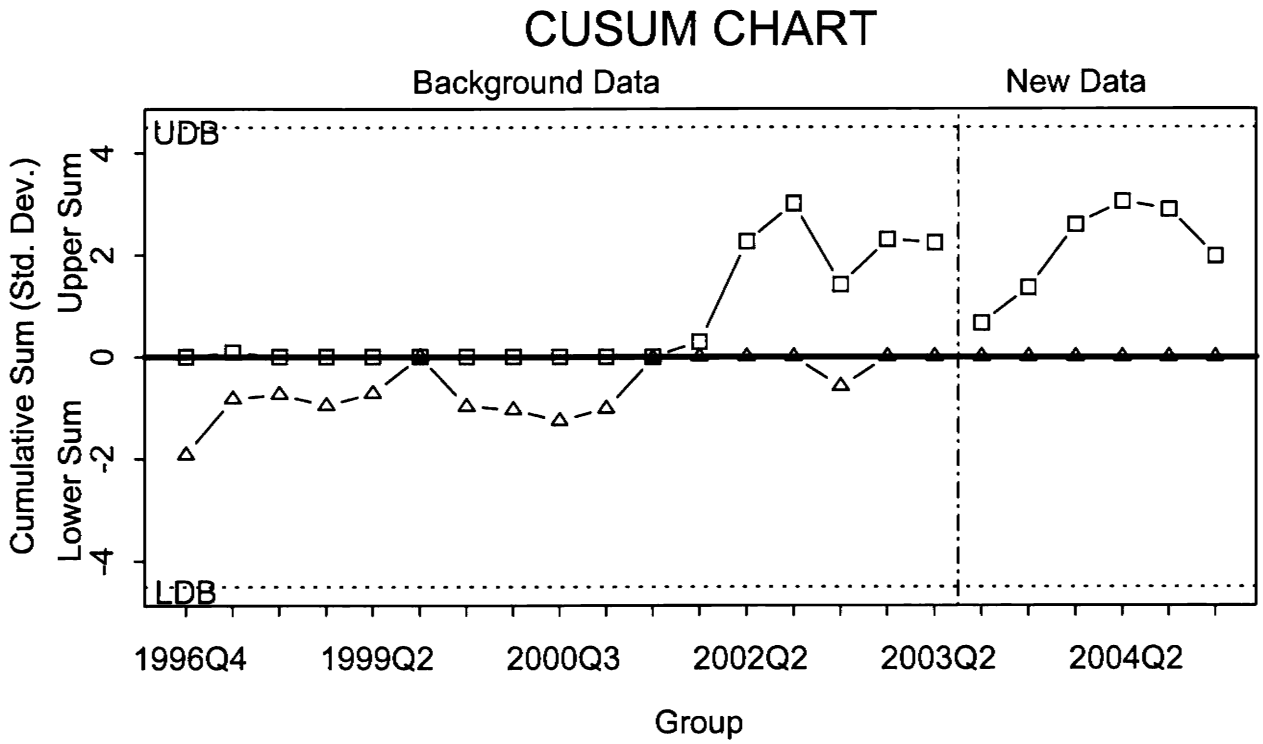


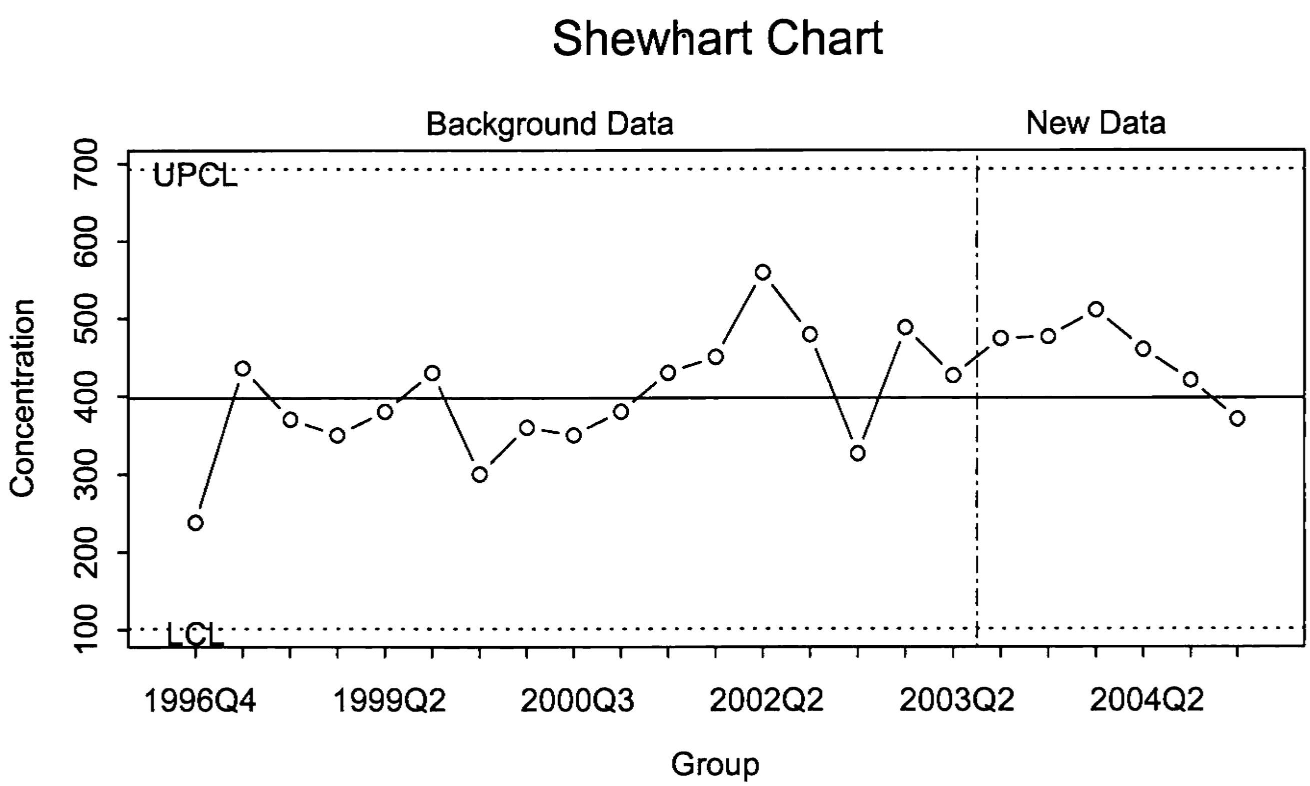
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-87D
Nitrogen, Ammonia
mg/l





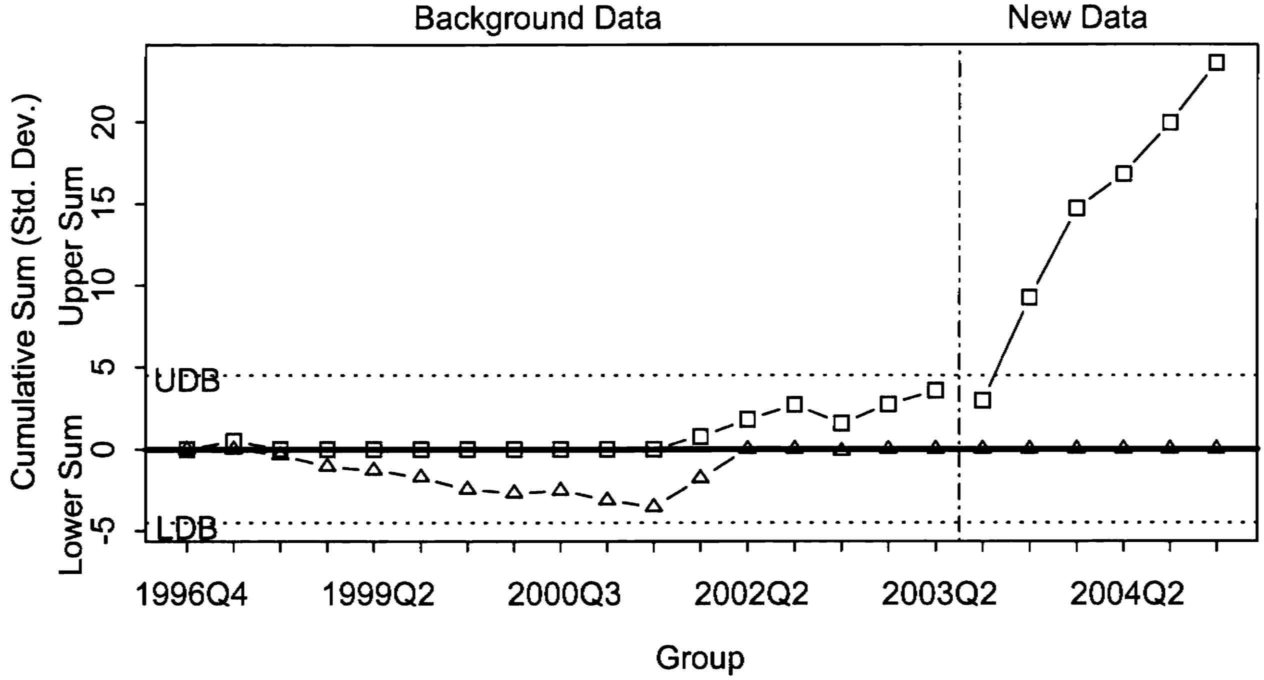
GEOMEGA

5/18/05

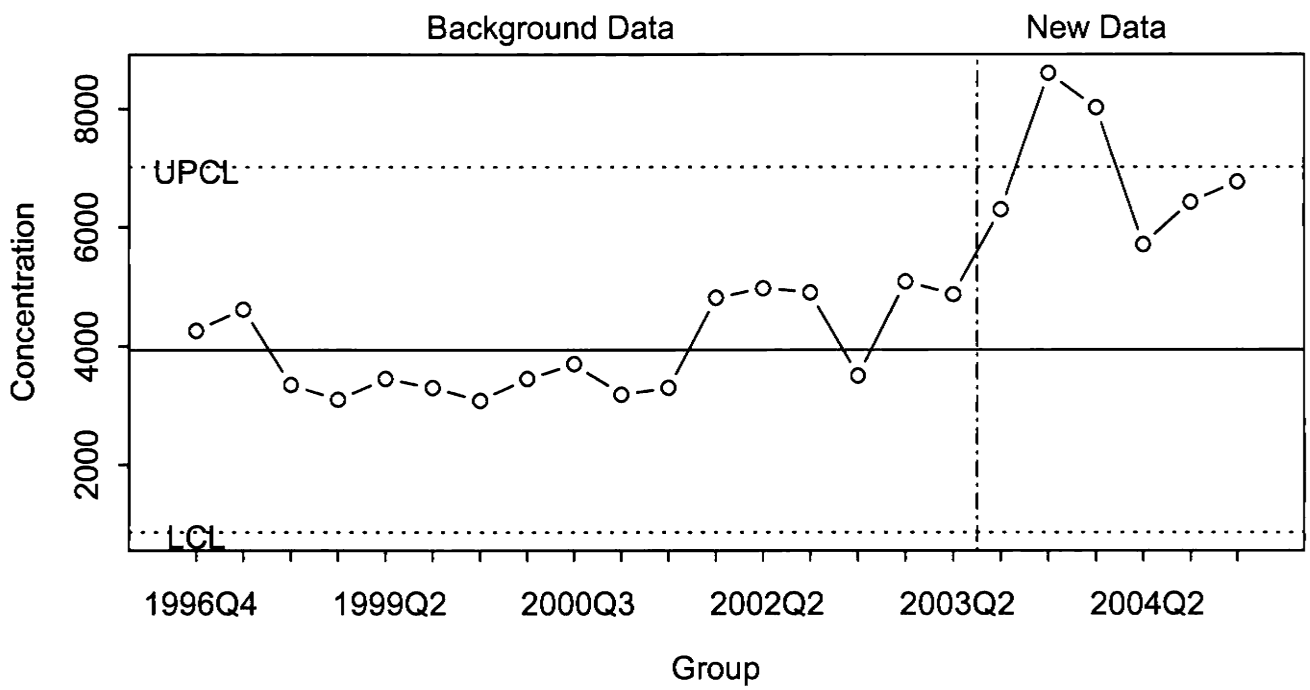
C03302C
Olin-Wilmington

GW-87D
Sodium, Dissolved
mg/l

CUSUM CHART



Shewhart Chart



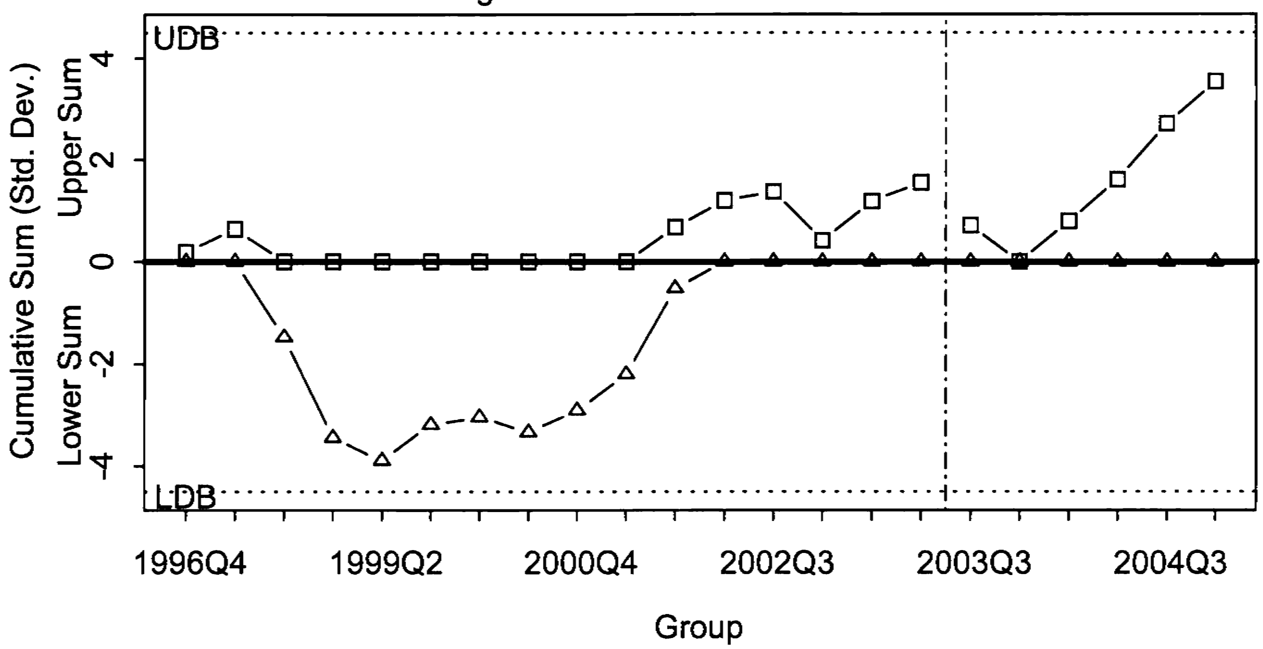
GEOMEGA

5/18/05

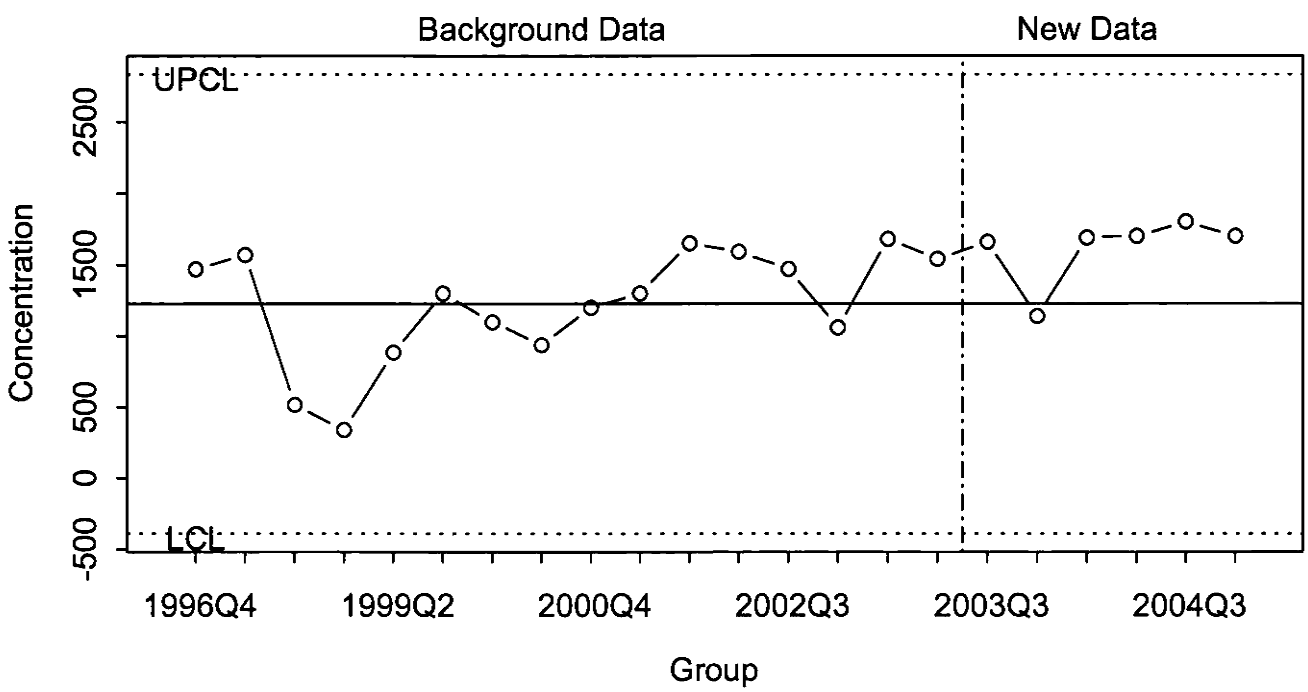
C03302C
Olin-Wilmington

GW-87D
Specific Conductance
umhos/cm

CUSUM CHART



Shewhart Chart

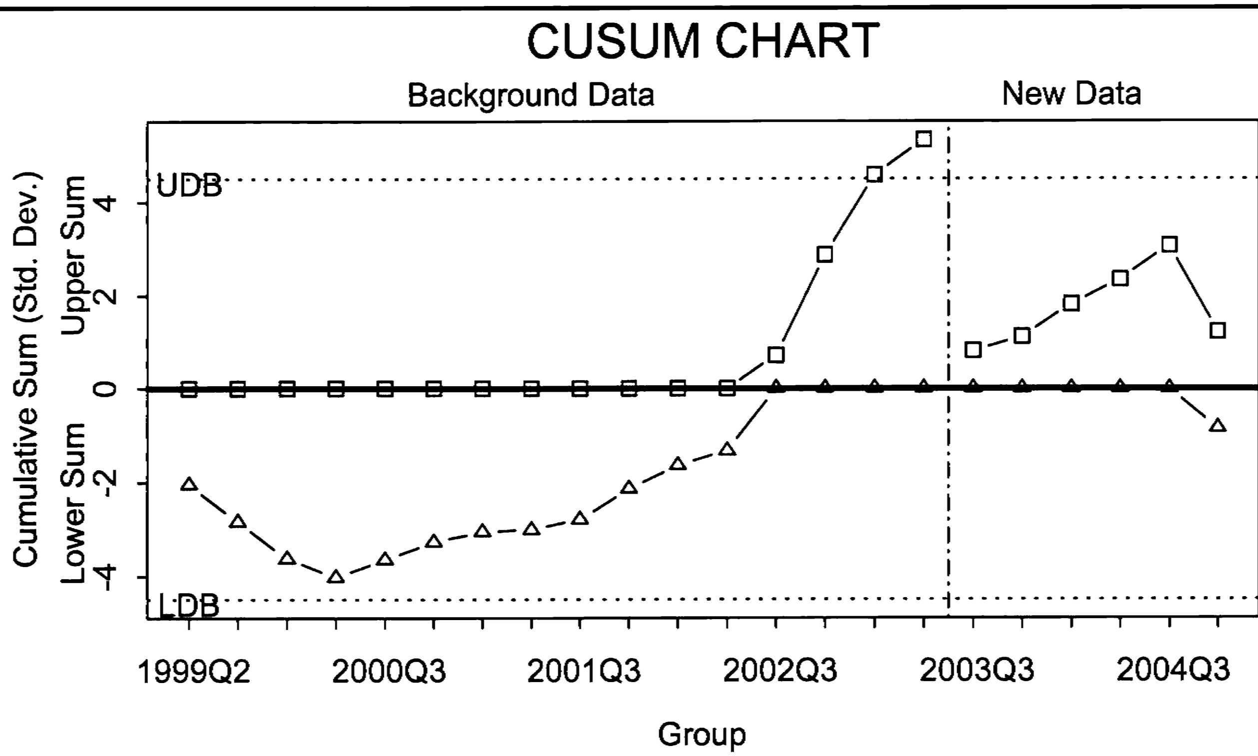


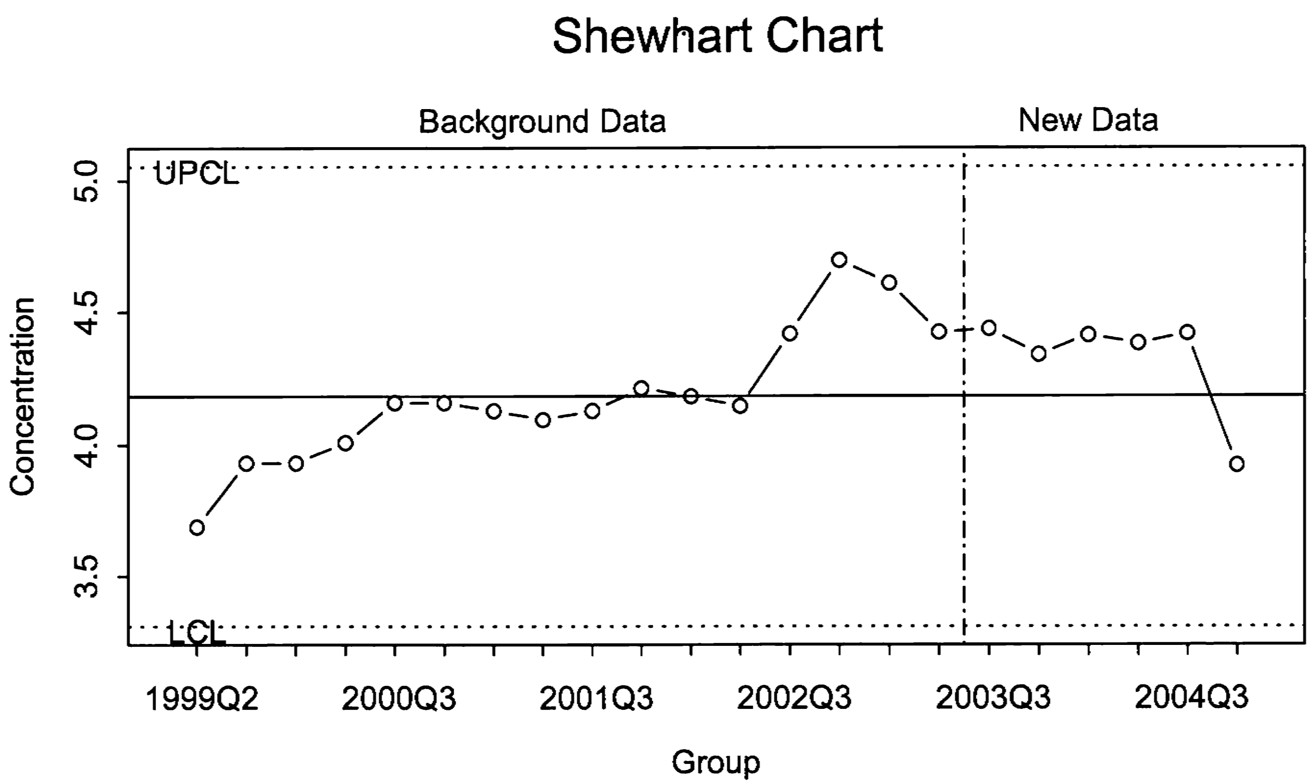
GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-87D
Sulfate as SO4
mg/l

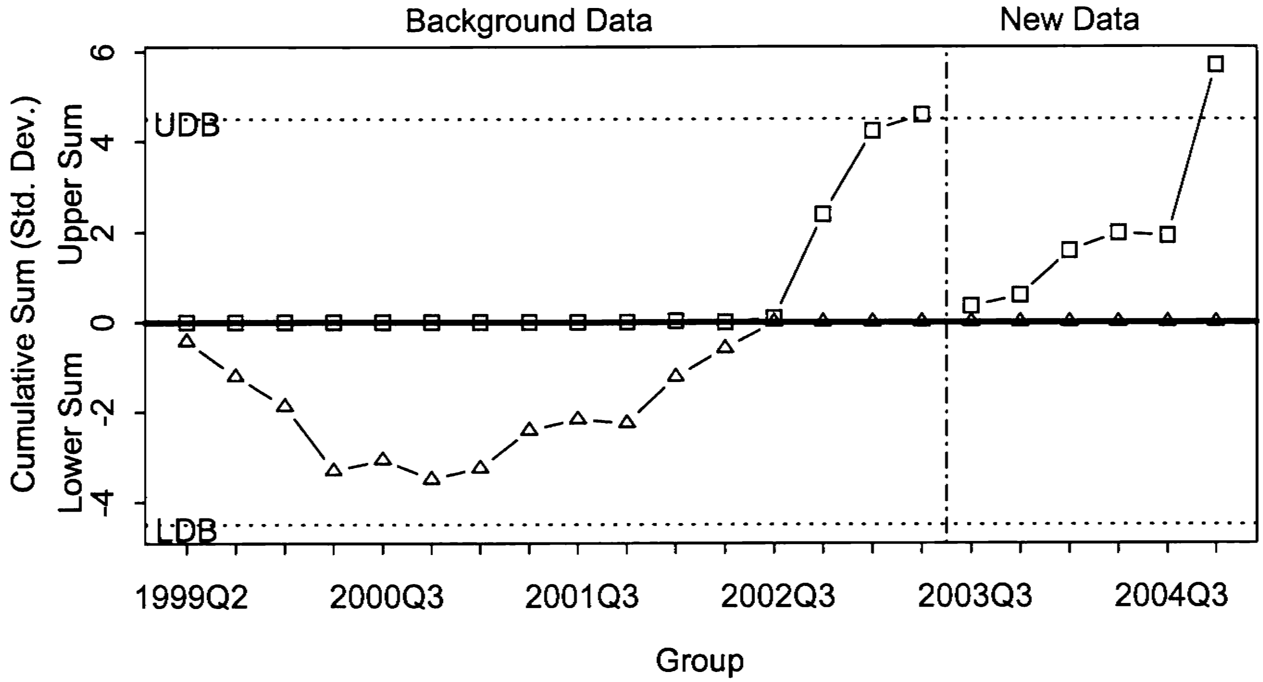




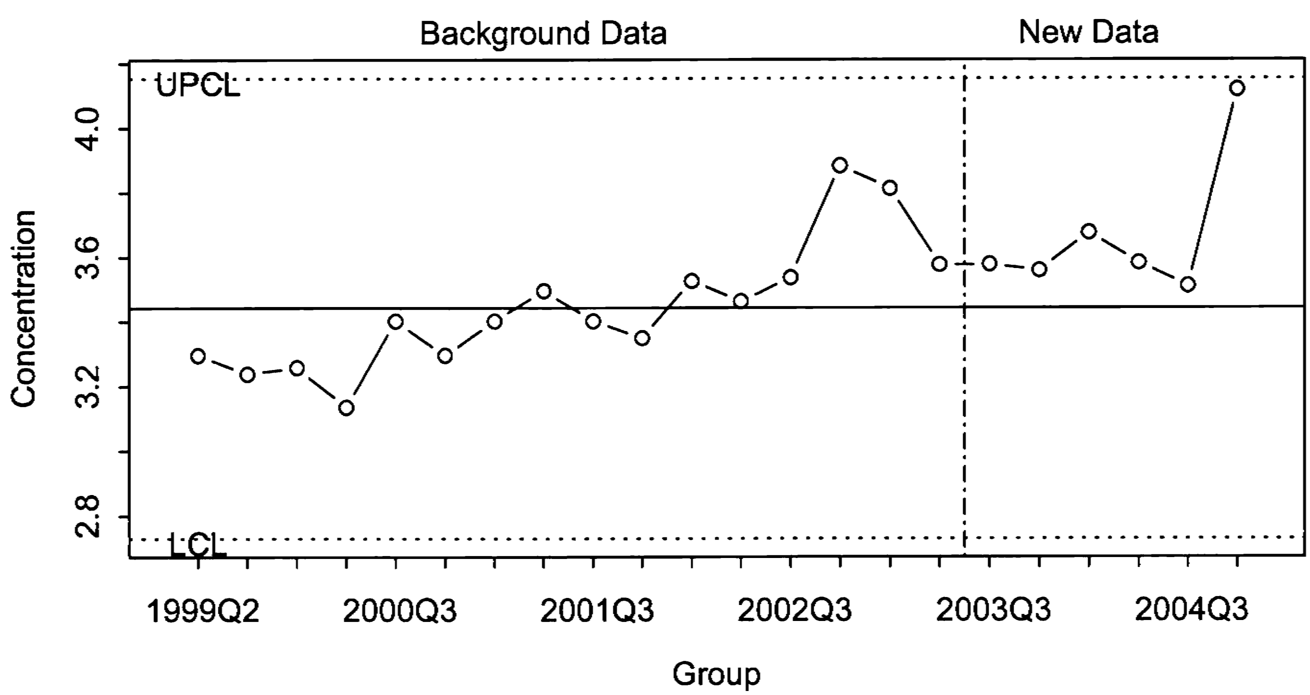
GEOMEGA
5/18/05
C03302C
Olin-Wilmington

GW-103D
Chloride
Log(mg/l)

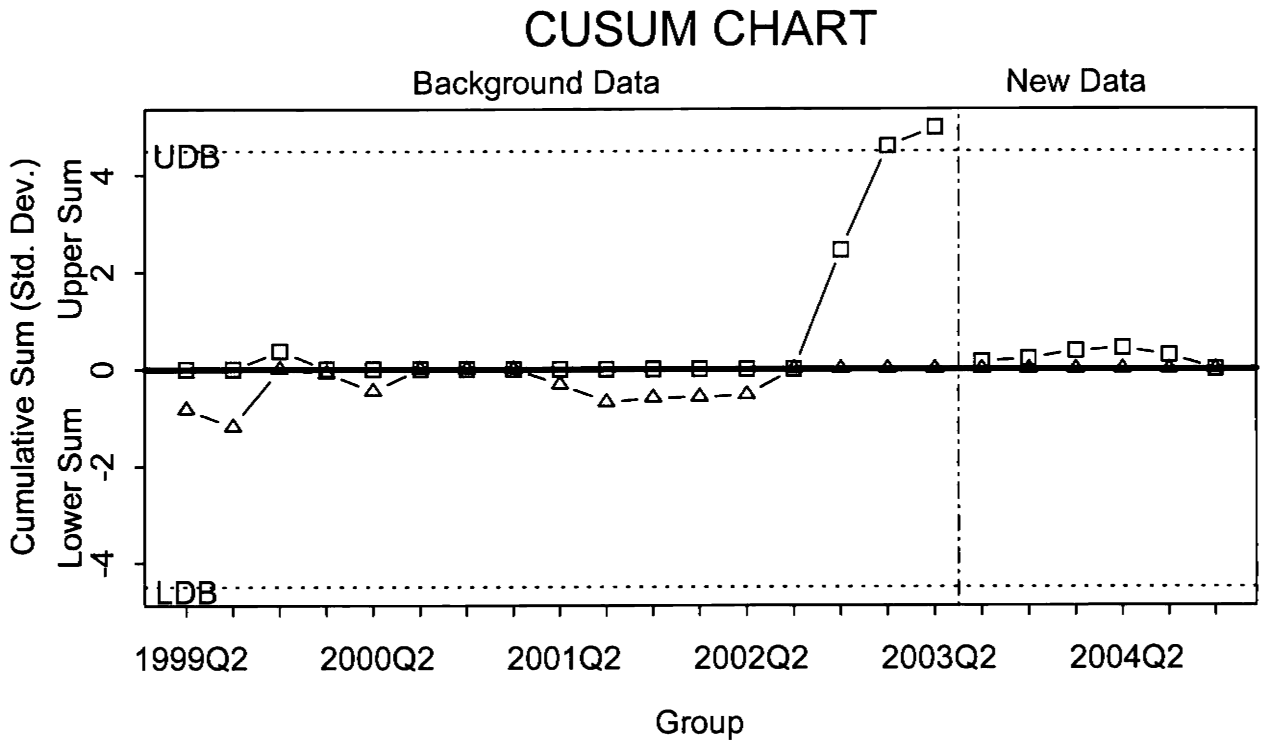
CUSUM CHART

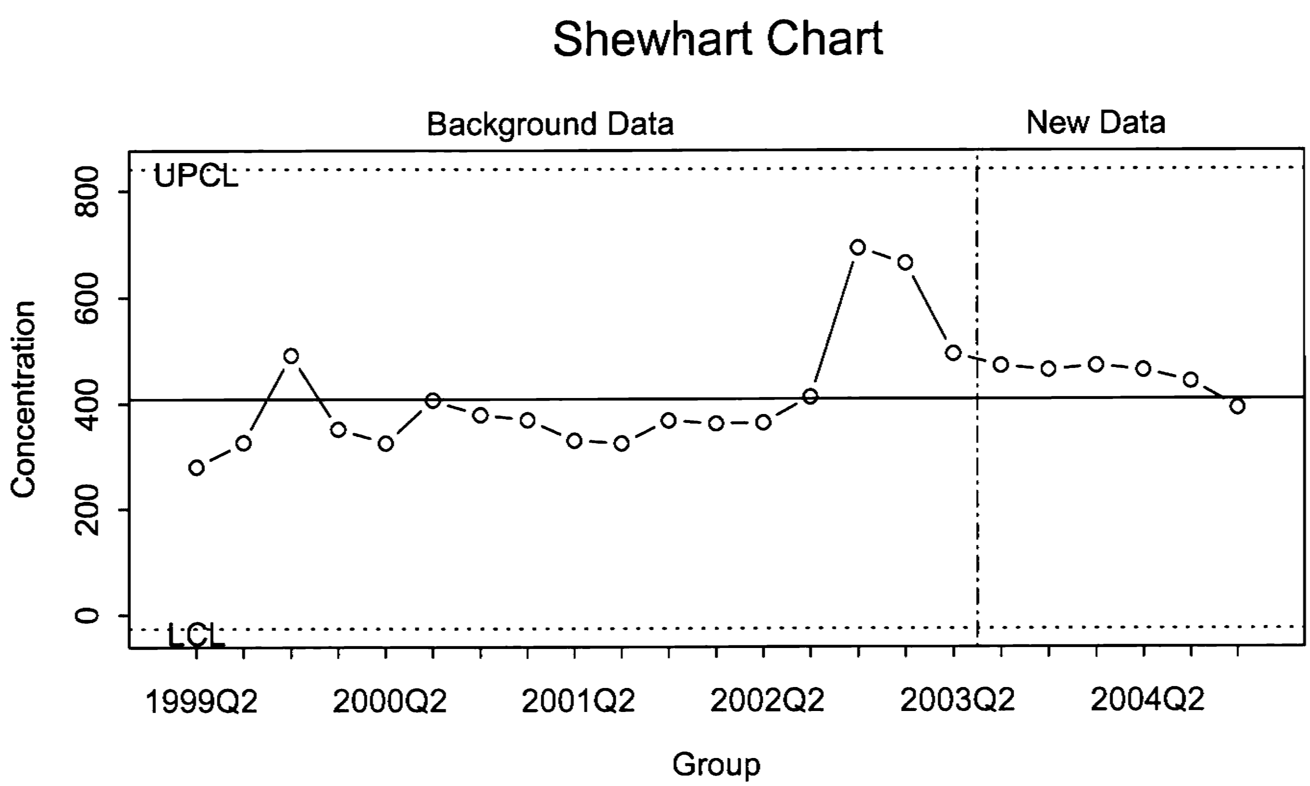


Shewhart Chart



GEOMEGA 5/18/05 C03302C Olin-Wilmington	GW-103D Sodium, Dissolved Log(mg/l)	





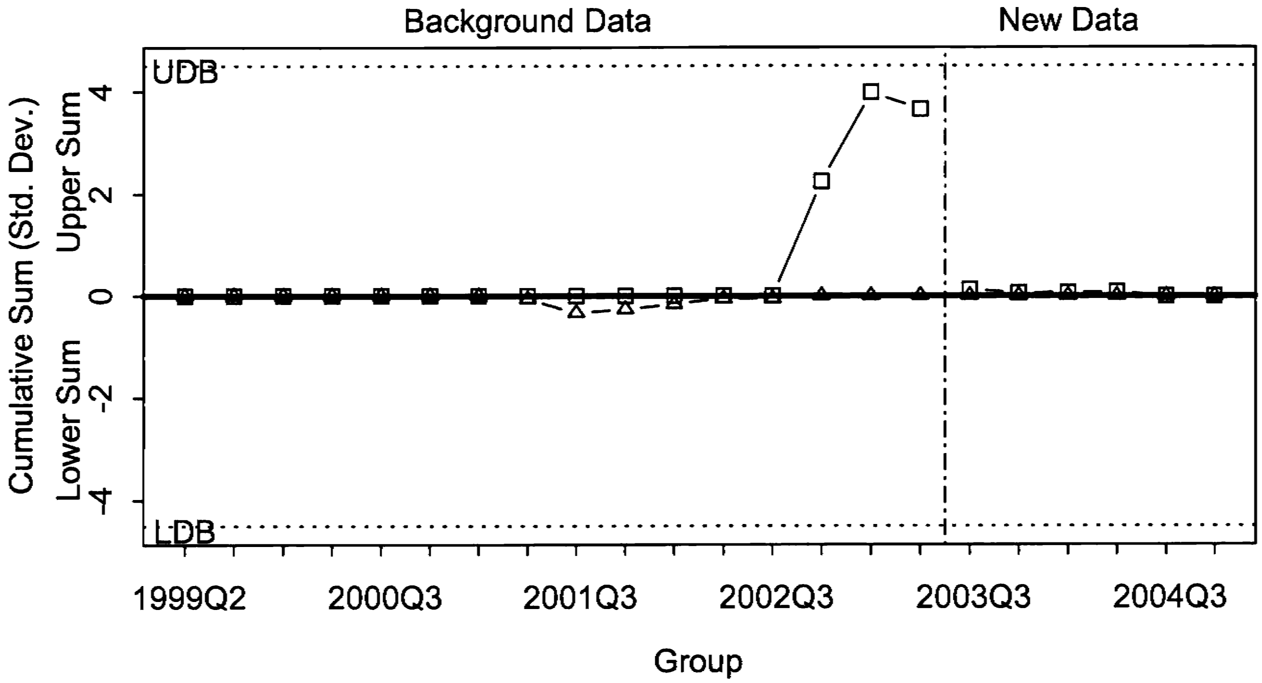
GEOMEGA

5/18/05

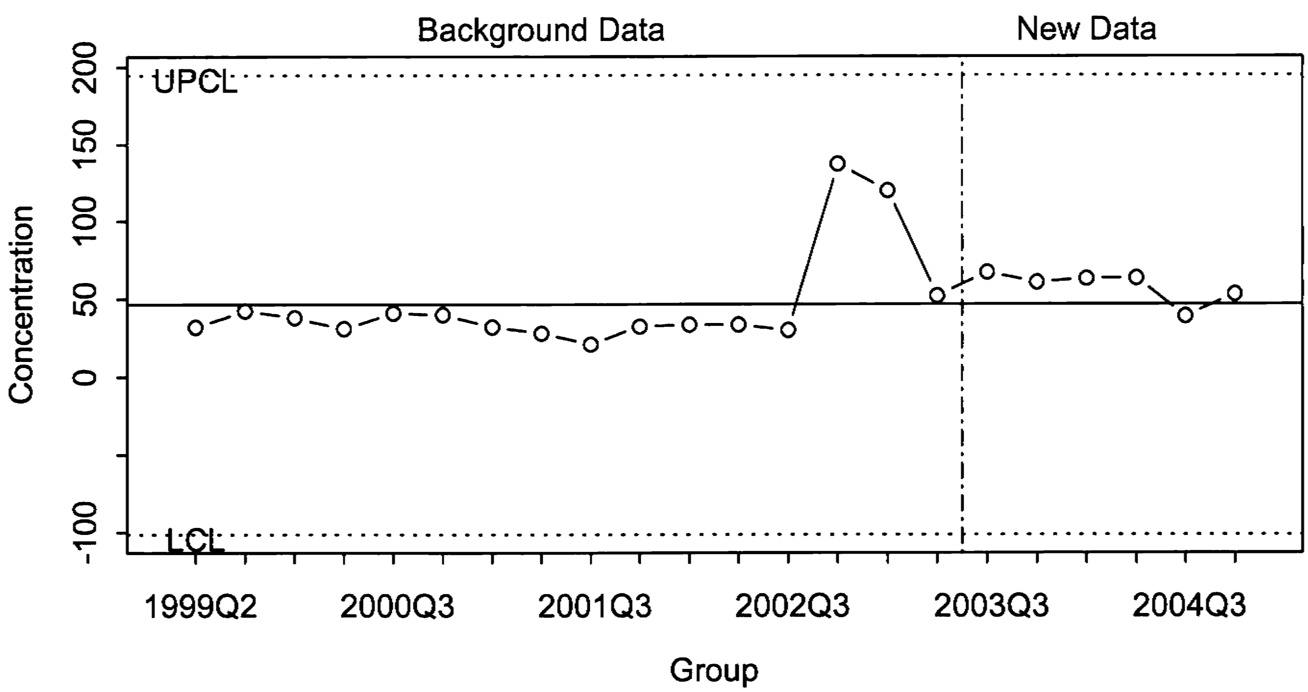
C03302C
Olin-Wilmington

GW-103D
Specific Conductance
umhos/cm

CUSUM CHART



Shewhart Chart



GEOMEGA

5/18/05

C03302C
Olin-Wilmington

GW-103D
Sulfate as SO4
mg/l